Harvesting Distributed Innovation Opportunities: Studies on Digital Innovation

by

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As Newton said, "If I have seen further, it is by standing on the shoulders of giants." I am undoubtedly a much lesser researcher than him. However, I am arguably much more fortunate than him, in that I have had two academic giants by my side since the very beginning of my research career. First, I would like to express my sincere gratitude to my supervisors, Professor Joe Nandhakumar and Professor Ola Henfridsson, the two giants who cared about my research so much, spent a lot of time discussing my research with me, responded to my questions promptly, and encouraged me when doubt set in. Without their extraordinary support, it would have been much harder to accomplish this research. I would also like to thank Dr Panos Constantinides, Professor Bendik Bygstad, and members of Warwick Business School's Information Systems and Management Group for their time, comments and suggestions, and for showing interest in my research. Finally, special thanks from the bottom of my heart go to my parents and friends who have given me strength to continue my study, and to participants in this research who provided me with the data that made this research possible.

Declarations

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. I, Gongtai Wang, declare that this thesis has been composed by myself under the supervision of Professors Joe Nandhakumar and Ola Henfridsson and has not been submitted in any previous application for any degree. This thesis takes a four-paper format. Chapters 3, 5 and 6 have been published in conference proceedings. Chapter 4 have been submitted to an international journal.

Publication

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Abstract

The permeation of digital technology into all aspects of the business world has created unstoppable momentum in the generation of novel products, services, business processes and business models, marking the prosperity of digital innovation. In order to succeed in the digital age, it is important for companies to understand the underlying logic of the generative power of digital innovation. Evidence is accumulating that this generative power arises from the distributed nature of digital innovation, which is often generated through a process of harvesting distributed innovation opportunities. However, there is limited understanding of how actors proactively appropriate distributed innovation opportunities to generate digital innovation.

To this end, in-depth studies were conducted on each of the four stages of the digital innovation process (discovery, development, diffusion and impact). Each study contributes new understandings to the digital innovation literature in terms of how actors take advantage of unique characteristics of digital technology to tap into distributed innovation opportunities in order to conceive a digital innovation, embody it in an outstanding form, promote its adoption, and surpass the original plan and gain extra benefits. The studies together provide a more comprehensive understanding of the appropriation of distributed innovation opportunities in digital innovation. Through the four studies, this thesis highlights the importance of shifting away from the "generativity as a concomitant result" mindset toward investigating the underlying logic of actors' proactive appropriation of distributed innovation opportunities.

CHAPTER 1 INTRODUCTION

Digital innovation is transforming the economic landscape. It often surprises us with the unprecedented novelty of its outcomes, its rapid processes, its broad impact, and its unpredictable after-effects. The generative power is often attributed to distinctive properties of digital innovation (Yoo et al., 2010b, 2012; Lee and Berente, 2012), and to understand the unique properties bears significance for innovation management (Nambisan et al., 2017).

An oft-cited unique property of digital innovation is its *distributed nature*, which refers to its exploitation of innovation opportunities distributed geographically, intellectually, and functionally in different human, material, and digital agents. Manifestations of the distributed nature include. For example, digital innovation may emerge at any stages of the innovation process, and any individual or group of actors may take the initiative in innovation generation (Nambisan et al., 2017, Nambisan, 2016, Fichman et al., 2014). Furthermore, not only intentional innovation activities but also activities that do not initially intend to be innovative may lead to innovative outcomes (Nambisan et al., 2017, Nambisan, 2016, Fichman et al., 2014).

The less bounded innovation process, less predefined innovation agency, and unintended innovative outcomes (Nambisan et al., 2017, Nambisan, 2016, Boland et al., 2007, Yoo et al., 2010b) together suggest that digital innovation is, by nature, distributed. In other words, drawing on distributed innovation opportunities is an essential form of innovation in the digital age. Here, *innovation opportunities* refer to circumstances that make an innovation possible. Hence, *distributed innovation opportunities* emphasize that the circumstances are not delineated but dispersed across human, material, and digital components and their interplay.

Research evidence is accumulating to show that distributed innovation opportunities are the primary source of digital innovation. For example, a digital product or service may continue to evolve alongside the accumulation of data generated through daily use by distributed users (Yoo, 2010); the value of a digital product or service may be created by an unexpected collective of distributed actors pursuing diverse goals (Bogers and West, 2012; Nambisan, 2016); and an organization's adoption of digital technology may result in unforeseen "waves of innovation" among distributed organizations (Boland et al., 2007). However, our understanding of how actors proactively appropriate distributed innovation opportunities is still limited.

To this end, this thesis studies how actors proactively draw on distributed opportunities for digital innovation. Guided by Fichman et al.'s (2014) conceptualization of the digital innovation process, four studies were conducted, on the discovery, development, diffusion and impact stages of digital innovation respectively. Through these four studies, this thesis contributes a more comprehensive understanding of how actors proactively appropriate distributed innovation opportunities (Table 1.1). The remainder of this section briefly introduces each study.

Table 1.1 Four studies on digital innovation.

Titles	Themes	Contributions to digital innovation literature
Combinatorial representational practice: How designers assemble representational practices to generate radical digital innovations (Wang et al., 2016)	Representational practice	Explicates how data homogenization and the flexibility of digital technology result in a loose coupling of representational practice components. Reveals two effects of combinatorial representational practice that either aid the coherence of idea communication or increase the serendipity of idea generation.
Standing out from the crowd: Digital innovation as reconstitution	Innovation novelty generation	Provides insights into how the layered architecture of digital technology results in digital innovation through movements of the design locus within and across product layers. Explains the generation of innovation novelty as a process in which design reconstitutes its architectural context.
Strategic swaying: How startups grow digital platforms (Wang and Nandhakumar, 2017)	Digital platform growth strategy	Illustrates how the utility of a digital platform to a user depends on the number of other users and their interactions, posing a critical challenge to startups in the early stages of their digital platform business. Offers understandings of how a platform owner may create and implement strategies to intervene proactively, not only online activities but also offline activities of users who lack technological, market or financial advantages.
Affordance-based conceptualization of adaptive use of enterprise systems (Wang and Nandhakumar, 2016)	Adaptive use of information technology	Highlights that users perceive possibilities of adaptive system use not only through technology affordances offered by the target system, but also through affordances offered by surrounding human actors. Expands current affordance-based research with human affordance, a dual-quality and relational view of affordance.

1.1 Combinatorial Representational Practice

Chapter 3 presents a study of representational practice in a design collaboration for digital innovation. It offers insights into how actors use digital technology to facilitate the communication and generation of product ideas. The research site is a Chinese company's project for an innovative digital theatre. During the project, even project members who lacked sufficient design knowledge and skills managed to communicate their abstract ideas efficiently and effectively using digital technology. Use of digital technology enabled the project members to appropriate the representational practices of distributed actors. This appropriation of diverse representational practices not only facilitated the communication of ideas, but also increased opportunities to generate new ideas. Hence, this case was suited to examining how actors appropriate distributed innovation opportunities to create digital innovation. In this study, innovation refers to increasingly clear and innovative product ideas, while distributed innovation opportunities refer to representational practices conducted by distributed actors that make an idea clearer or more innovative.

The findings reveal that data homogenization and the flexibility of digital technology enable a loose coupling between representational practice components (conception, creation and use). This loose coupling enables project members to engage in a flexible representational practice, referred to here as "combinatorial representational practice". Whether or not they have the necessary design knowledge and skills, this practice allows project members actively to initiate representational practices by combining distributed representational practice components contributed by different actors. Combining distributed representational practice components brings rich information that helps to clarify a represented and communicated idea. The richness of the information may also increase opportunities to make serendipitous discoveries leading to the generation of new ideas.

This study contributes to the digital innovation literature with an understanding of distinctive characteristics of digital technology and how they can be appropriated to improve the collaborative design work of diverse actors. It also contributes novel insights to the boundary object, agile design and general design literature. It has implications for practice in terms of the design of design tools and the organization of design projects.

1.2 Standing Out from the Crowd

Chapter 4 presents a study of novelty generation in product development involving digital innovation. Its purpose is to learn how actors progressively elevate their product from mediocre to extraordinary. The research site is the same as that investigated in the previous study. However, it differs in that its analysis focuses particularly on technical documents and interviewees' explanations of those documents, seeking to understand the logic behind documented design decisions. Longitudinal data collection provided abundant information to investigate the evolving process of the project. This case fits well with the research purpose because it shows how designers continuously capture emerging innovation opportunities distributed across different product layers, enabling their designs to evolve and become progressively more distinctive. In this study, innovation refers to the novelty of the final product, while distributed innovation opportunities refer to design work distributed across different product layers that inspires or compels design rework.

Data analysis started by identifying reconstitutive cycles — the distinct moments of design evolution in the making of digital innovation. Zooming in on 16 reconstitutive cycles, the data analysis reveals that movement of the design locus within and across product layers results in intra- and inter-layer reconstitutive cycles. The two types of reconstitutive cycle produce extensive and intensive design evolutions, which aggregatively increase the novelty of an innovation.

This study contributes to the digital innovation literature by providing an understanding of how the layered architecture of digital innovation enables novelty generation as a process of reconstituting the architectural context of design. The novelty-as-reconstitution view adds to the current literature with an understanding of how the design of digital innovation rebuilds what it is building on, explaining how the boundaries of innovation space become fluid. Furthermore, the design lens developed in this study potentially reveals more useful and interesting insights into design in the digital age, as the design process becomes increasingly opportunistic, and the division between design-for-function and design-for-aesthetics becomes blurred.

1.3 Strategic Swaying

Chapter 5 presents a study of the strategic practice of growing the user base of digital innovation. It examines how a platform owner involves distributed users to increase the platform's user base. The case company is a Chinese digital startup that has ingeniously and successfully developed its platform business. It is suited to studying how actors appropriate distributed innovation opportunities to scale up digital innovation. In this study, innovation refers to the digital platform that impacts on the traditional industry that it evades, while distributed innovation opportunities refer to the network externality distributed across diverse platform users that forms a positive feedback loop to expand the platform.

The data analysis reveals that digital platform growth can be achieved through both online and offline efforts that appropriate not only technological, market and financial resources but also other factors such as social means. The study identifies a strategic practice named “strategic swinging”, in which a company moves between two sides of its platform to form and execute different strategies to increase its user base. This study also identifies two types of strategy. The first, called “enfolding”, refers to organizing service providers and standardizing their offerings. The second, “socializing”, refers to promoting the establishment and growth of a society of service users. These two strategies can tap into positive network effects to form a virtuous feedback loop to scale up a platform’s user base.

In terms of implications for research, the study contributes to the digital innovation literature by providing an understanding of the importance of aligning online and offline efforts to grow the user base of a digital platform. It also underlines the importance of an all-round perspective on digital platform growth strategies, which suggests supplementing technology-, market- and finance-focused views with all other potentially available resources. In terms of implications for practice, this study identifies and offers ready-to-use strategies for practitioners to implement in their businesses.

1.4 Affordance-Based Conceptualization of Adaptive Use of Enterprise Systems

Chapter 6 presents a study of the adaptive use of information systems. Its purpose is to understand how users maximize the benefits of a given information system by using it in a way beyond the original plan. The research site is an ongoing information system project in a top Chinese chemical company renowned for its successful system use, which has achieved remarkable improvements in its business operations. This case is suited to studying how innovation opportunities are distributed, not only in an innovative technological offering, but also in other technological artefacts and human actors that surround its use. In this study, innovation refers to the new use of a digital technology that maximizes its benefits, while distributed innovation opportunities refer to new possibilities to work with the technology in question, informed by surrounding technological artefacts and human actors and their interrelationships.

The data analysis reveals that adaptive use is common and essential, leading to additional benefits from a given information system. Users perceive adaptive use possibilities not only through the technology affordances of the system, but also through affordances offered by surrounding technological artefacts and human actors. This nested affordance, aggregated from the interrelated affordances of the system of interest and its surrounding technological artefacts and human actors, ultimately shapes users’ perceptions of its possibilities and their decisions on use. Furthermore, this nesting process is not a simple sum of aggregated affordances, as it may reverse the constraints of lower-level use to enable higher-level use.

This study makes several contributions to the literature. First, it offers a more detailed explanation of how users perceive adaptive use possibilities. Second, it introduces the concept of human affordance, highlighting the essential influence of surrounding human actors on users' system use. Third, it explains the relational view and dual quality of the affordances of system use. All these have the potential to inform a deeper investigation and understanding of how distributed innovation opportunities are recognized and appropriated through interactions between human actors and digital technology. This study has implications for practice in that it highlights the importance of taking into account the physical presence of other staff when implementing and managing a technology.

The remainder of this thesis is organized as follows. Chapter 2 provides a review of the literature to clarify the gap in knowledge addressed in this thesis through the collection of four studies. Chapters 3 to 6 present the four studies, and Chapter 7 concludes with a general discussion of their implications for research and practice.

CHAPTER 2 LITERATURE REVIEW

What is the significance of digital innovation as an independent research field? The earliest use of the term "digital innovation" can be traced back to the 1980s. If a very broad definition of digital innovation is adopted, its origin can be traced as far back as the 1830s when the first digital technology (the telegraph) was developed (Phillips, 2000). However, as this chapter reveals, the rise of digital innovation as an independent field only started around 2009. This gives rise to the question of how the digital innovation acclaimed today differs from previous innovation which also involved digital technology.

To answer this question, this chapter first investigates the essential construct of digital innovation. It then recognizes and explains its distributed nature as a critical characteristic that distinguishes today's digital innovation from previous innovation that also involved digital technology but was less concerned with this characteristic. The chapter concludes by relating the distributed nature of digital innovation to digital innovation processes, in order to clarify the conceptual connections between the four studies in this thesis.

2.1 Definitions of Digital Innovation

A definition is a vehicle for a theoretical idea which communicates essential characteristics of a phenomenon under academic consideration (Suddaby, 2010). In this regard, reviewing definitions of digital innovation and analyzing differences between competing definitions will help provide an understanding of the essential construct of the digital innovation concept and the distinctive characteristic of the digital innovation phenomenon.

To this end, an extensive literature review was conducted. In addition to literature relating closely to the research themes of the four studies in this thesis, a more general search was conducted to incorporate literature less related to the themes but seeking explicitly to define the digital innovation concept. The search was carried out using the Business Source Complete and Google Scholar databases, which allow full text searches of documents. Search terms are as follows:

("digital innovation is defined") OR ("digital innovation refers") OR ("definition of digital innovation") OR ("define digital innovation") OR ("defines digital innovation") OR ("digital innovation to refer") OR ("by digital innovation").

Papers were also downloaded from the Scopus and AIS eLibrary databases, retrieved using the broad search term "digital innovation" to avoid overlooking relevant works. Then, redundant and non-peer-reviewed papers were removed from the sample collected from the four databases, and the remaining papers were analyzed for their definitions of digital innovation (see Table 2.1).

Table 2.1 Definitions of digital innovation.

Literature	Definition	Type	Year	Title	Reference
Nambisan et al. (2017)	"the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology."	Original	2017	Digital Innovation Management: Reinventing Innovation Management Research in A Digital World	N/A
Hukal and Henfridsson (2017)	"the co-creation of novel offerings through recombination of digital and/or physical components."	Original	2017	Digital Innovation - A Definition and Integrated Perspective	
Watson et al. (2017)	"the creation of a novel outcome that relies upon digitization for its transformative effects."	Extended	2017	Physical and Digital Innovation in Shipping: Seeding, Standardizing, and Sequencing	Fichman et al. (2014)
Saldanha et al. (2017)	"broadly defined as a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT."	Reported	2017	Leveraging Customer Involvement for Fuelling Innovation: The Role of Relational and Analytical Information Processing Capabilities	Fichman et al. (2014)
Dürr et al. (2017)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2017	Navigating Digital Innovation – The Complementary Effect of Organizational and Knowledge Recombination	Yoo et al. (2010b)
Huang et al. (2017)	"the recombination of digital components in a layered, modular architecture to create new value-in-use to users or potential users of a service."	Synthesized	2017	Growing on Steroids: Rapidly Scaling the User Base of Digital Ventures Through Digital Innovation	Yoo et al. (2010b) Lusch and Nambisan (2015)
Göbel and Cronholm (2016)	"a broad definition of digital innovation, which is in line with who describes an innovation as, '…an idea, practice, or project that is perceived as new by an individual or other unit of	Extended	2016	Nascent Design Principles Enabling Digital Service Platforms	Rogers (2003)

Literature	Definition	Type	Year	Title	Reference
	adoption’. However, to be an IT service innovation we add that the innovation is enabling value and is composed of or enabled by IT.”				
Perry and Pollock (2016)	“a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT.”	Reported	2016	Digital Identity in Mobile Products for Digital Innovation	Fichman et al. (2014)
Obwegeser and Bauer (2016)	“a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT.”	Reported	2016	Digital Innovation and the Becoming of an Organizational Identity	Fichman et al. (2014)
Zavolokina et al. (2016a)	“product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT.”	Reported	2016	Fintech – What's in a Name?	Fichman et al. (2014)
Herterich and Mikusz (2016)	“the carrying out of new combinations of digital and physical components to produce novel products.”	Reported	2016	Looking for a Few Good Concepts and Theories for Digitized Artifacts and Digital Innovation in a Material World	Yoo et al. (2010b)
Zavolokina et al. (2016b)	“product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT.”	Reported	2016	The Fintech Phenomenon: Antecedents of Financial Innovation Perceived by the Popular Press	Fichman et al. (2014)
Abrell et al. (2016)	“carrying out new combinations of digital and physical components to produce novel products and services.”	Synthesized	2016	The Role of Users and Customers in Digital Innovation: Insights from B2B Manufacturing Firms	Yoo et al. (2010b)
Yang et al. (2015)	“any innovation enabled by digital technologies that leads to the creation of new forms of digitalization.”	Paraphrased	2015	Digital Services Innovation for Aging-In-Place	Yoo et al. (2010b)
Wang et al. (2015)	“an idea, practice, or object that is perceived as new and is embodied in and enabled by digital technology.”	Paraphrased	2015	How Do Community Ecology and Structure Shape Digital Innovation Strategy?	Fichman et al. (2014)

Literature	Definition	Type	Year	Title	Reference
Ciriello and Richter (2015)	“product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT.”	Reported	2015	Idea Hubs as Nexus of Collective Creativity in Digital Innovation	Fichman et al. (2014)
Kurti (2015)	“any innovation that is ICT enabled that results in creation of new forms of digitalization.”	Paraphrased	2015	Inherent Cognitive Dependencies in The Transformation of Business Models from Non-Digital to Digital	Yoo et al. (2010b)
Hildebrandt et al. (2015)	“the carrying out of new combinations of digital and physical components to produce novel products.”	Reported	2015	Entering the Digital Era – The Impact of Digital Technology-Related M&As on Business Model Innovations of Automobile OEMs	Yoo et al. (2010b)
Ramilo and Embi (2014)	“the use of new digital channels, digital tools and relevant methodologies to improve the operation of architectural organizations, delivery of services, and building design.”	Original	2014	Critical Analysis of Key Determinants and Barriers to Digital Innovation Adoption among Architectural Organizations	N/A
Fichman et al. (2014)	“a product, process, or business model that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT.”	Original	2014	Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum	N/A
Åkesson and Thomsen (2014)	“combining digital and physical components in new ways making products programmable, addressable, sensible, communicatable, memorable, traceable and associable.”	Paraphrased	2014	Digital Innovation and Social Dilemmas	Yoo et al. (2010b)
Lund (2014)	“the embedding of digital computer and communication technology into a traditionally non-digital product.”	Synthesized	2014	Activities to Address Challenges in Digital Innovation	Henfridsson et al. (2009)
Eriksson and Åkesson (2013)	“innovations enabled by ICT, and combining digital and physical components in new ways.”	Paraphrased	2013	Managing Digital Innovation in Newspaper Organizations	Yoo et al. (2009)

Literature	Definition	Type	Year	Title	Reference
Thomsen and Åkesson (2013)	"innovations enabled by digital technology."	Paraphrased	2013	Understanding ISD and Innovation Through the Lens of Fragmentation	Yoo et al. (2009)
Hylving and Schultze (2013)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2013	Evolving the Modular Layered Architecture in Digital Innovation: The Case of the Car's Instrument Cluster	Yoo et al. (2010b)
Akram (2013)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2013	Value Creation in Digital Ecosystem – a Study of Remote Diagnostics	Yoo et al. (2010b)
Rönnbäck and Eriksson (2012)	"the use of information and communication technology as a driving force for innovation that has an impact on the structure, processes and organizational landscape."	Paraphrased	2012	A Case Study on Quality Management and Digital Innovation: Relationship and Learning Aspects	Yoo et al. (2010b)
Svahn and Henfridsson (2012)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2012	The Dual Regimes of Digital Innovation Management	Yoo et al. (2010b)
Hylving et al. (2012)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2012	The Role of Dominant Design in a Product Developing Firm's Digital Innovation	Yoo et al. (2010b)
Akram (2012)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2012	Towards Servitization in the Age of Digital Innovation: A Case from Vehicle Industry	Yoo et al. (2010b)
Svensson and Eriksson (2012)	"new combinations of digital and physical components to produce novel products or services or to the embedding of digital computer and communication technology into a traditionally non-digital product or service."	Synthesized	2012	The Role of Social Aspects in Digital Innovation Networks	Yoo et al. (2010b) Henfridsson et al. (2009)
Akram and Åkesson (2011)	"the realization of new combinations of digital and physical components to produce novel products, while the services enabled by such digitalization are called digital services and innovation in services is called digital service innovation."	Extended	2011	A Research Framework to Study: How Digital Service Innovation Transforms Value Networks	Yoo et al. (2010b)

Literature	Definition	Type	Year	Title	Reference
Chowdhury and Akesson (2011)	"the carrying out of new combinations of digital and physical components to produce novel products."	Reported	2011	A Proposed Conceptual Framework for Identifying the Logic of Digital Services	Yoo et al. (2010b)
Yoo et al. (2010b)	"the carrying out of new combinations of digital and physical components to produce novel products."	Extended	2010	The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research	Schumpeter (1934)
Burtch et al. (2010)	"a broad spectrum of process and product innovations enabled by digital technology, including information systems and robotics."	Original	2010	Digital Innovation and Craftsmanship: The Case of C. F. Martin & Company	N/A
Svahn et al. (2009)	"the new waves of organizational, technical, and cognitive innovation practices that follow the digitization of physical artifacts."	Synthesized	2009	A Threesome Dance of Agency: Mangling the Sociomateriality of Technological Regimes in Digital Innovation	Andersson et al. (2008) Boland et al. (2007) Henfridsson et al. (2009) Yoo et al. (2008) Zammuto et al. (2007)
Henfridsson et al. (2009)	"the embedding of digital computer and communication technology into a traditionally non-digital product."	Original	2009	Path Creation in Digital Innovation: A Multi-Layered Dialectics Perspective	N/A

This analysis led to the identification of five types of definition: 1) original definitions are those presented for the first time; 2) extended definitions add new constructs to an original definition; 3) synthesized definitions integrate definitions or arguments from previous studies, 4) paraphrased definitions express existing definitions in different words; and 5) reported definitions are direct quotations of existing definitions. This classification is useful for understanding the development of digital innovation research. Original and extended definitions add new constructs to the concept, and analyzing them may reveal the essential construct, while analyzing synthesized, paraphrased and reported definitions may reveal how research interest has evolved.

Through analysis of original and extended definitions, four constructs of the digital innovation concept were identified: 1) input (non-digital and digital components), 2) process (changing, combining and creating), 3) output (products, services, processes and business models), and 4) effect (perceived novelties, improvements and consequent changes). Adopting these constructs as a framework, the definitions were further analyzed to investigate chronological changes in the content of each construct.

As shown by Henfridsson et al.'s (2009) original definition and one of the two frequently-cited definitions (Yoo et al., 2010b), early digital innovation research focused on product innovation. Almost all studies before 2015 adopted these two definitions. However, as subsequent original and extended definitions show, the scope of digital innovation research gradually expanded to process, service and business model innovation. Since 2015, citations of Fichman et al.'s (2014) broad definition have become more frequent. Fichman et al's (2014) research reveals that the subsequent incorporation of new elements was not a shift in, but an expansion of, the research focus. In other words, it is difficult to classify a digital innovation as clearly either a product, process, service or business model innovation. Rather, digital innovation often entails the transformation of diverse aspects of a business, which may involve multiple types of innovation. This finding is in line with Nambisan et al.'s (2017) argument, which also reveals an essential characteristic of digital innovation – its distributed nature. This deserves further investigation, and the next section discusses it by reviewing the digital innovation literature with the above four-construct framework in mind.

2.2 The Distributed Nature of Digital Innovation

Having identified four constructs in the digital innovation concept, it is possible to examine digital innovation in greater detail. Although all the definitions incorporate the four constructs simultaneously, examining which construct takes the lead in a digital innovation enables differences between digital innovations to be identified in terms of the timing of innovative leaps.

First, digital innovation may occur in the form of the introduction of new digital and non-digital components, for example by inviting external contributions of ideas to internal innovation activities with digital technology to create innovative products and services (Zhang et al., 2012). Second, digital innovation may involve new ways of using given digital and non-digital components, for instance, a "creative use" of digital technology (de Castro et al., 2000) or "reuses of ideas" enabled by digital technology (Howard et al., 2011). Third, digital innovation may entail digital technology-enabled novel offerings, such as Google Maps (Yoo, 2010). Finally, digital innovation may appear as an unexpected cascade of derivative innovations. For example, a company's adoption of new computer-aided design software may lead to changes in other organizations' business practices, eventually revolutionizing the whole industry (Boland et al., 2007).

Any of the four constructs may take the lead in digital innovation. However, digital innovation most commonly starts from a construct and gradually gains sufficient impetus to generate subsequent changes in other constructs. In other words, digital innovation is the end result of an accumulation of initial and follow-up changes. This accumulating process is often characterized by porous boundaries between digital innovation processes and blurred distinctions between processes and outcomes (Nambisan, 2016; Nambisan et al., 2017), less pre-defined and more dynamic innovation initiatives (Nambisan, 2016), and deepening entanglement of human, material and digital agencies (Svahn et al., 2009, Yoo, 2010). All these characteristics indicate the complexity of digital innovation (Yoo et al., 2010b).

An increasing number of studies shows that at the root of such complexity is the distributed nature of digital innovation. Von Hippel (1988) and Van de Ven et al. (2008) pointed out some time ago that innovation is, by nature, distributed. This distributed nature is even more prominent and relevant in digital innovation because of the unique characteristics of digital technology (Yoo et al., 2010b, Yoo, 2013). It is not only a by-product of innovation activities, but also a critical generative source of innovation in the digital age (Zhang et al., 2012, Yoo et al., 2008, Zittrain, 2006). The fundamental logic of digital innovation taps into this nature, making it distinct from other types of innovation that also involve digital technology.

The distributed nature of digital innovation may be attributed to the involvement of heterogeneous innovations and actors. In studies of conventional innovation, researchers have been more concerned with how an innovation is created by a single actor and then diffused in a context composed of homogeneous actors (Yoo et al., 2008). However, digital innovation may require diverse innovations (Yoo et al., 2008) and the participation of diverse professionals, and even laypeople (Fayard et al., 2016, Constantinides, 2012). A digital innovation may be diffused through a network of heterogeneous actors (Yoo et al., 2008) and may produce a cascade of heterogeneous derivative innovations (Boland et al., 2007).

This distributed nature is attributable to the use of digital technology that eases the mobilization of resources distributed widely across geographical and intellectual space. Digital technology facilitates this mobilization in two respects: connection and communication. In terms of connection, the ubiquity of digital technology gives an actor greater access to intellectual resources stored in either other actors' memories or in digital media. Such enriched "transactive memory" increases the available knowledge (Majchrzak et al., 2013) necessary for the actor to conceive and conduct innovation activities. In terms of communication, digital technology enhances innovation agents' "cognitive translation" and "social translation" (Yoo et al., 2008). As previously discussed, collaboration between heterogeneous actors is increasingly essential to digital innovation. In order to use heterogeneity effectively as a resource, actors must share, understand and reflect on each other's ideas. Digital technology serves this purpose by enhancing actors' ability to transfer abstract ideas to concrete representations. It offers an efficient common ground for innovation agents to communicate their diverse understandings and align their innovation activities (Boland et al., 2007).

As discussed in the next section, the distributed nature of digital innovation requires a move away from the "organizational pull" and "technological push" views (Cooper and Zmud, 1990) that regard it mainly as an outcome. This suggests examining digital innovation as a whole process, from the very beginning of an abstract idea to the creation and implementation of a change, and to the generation of derivative changes (Fichman et al., 2014, Nambisan et al., 2017).

2.3 Digital Innovation Process

Fichman et al. (2014) define four stages in the digital innovation process, namely discovery, development, diffusion and impact. According to their definition, at the discovery stage, actors create new ideas through their own internal creative processes, or look for existing offerings in the external environment that are ready for use or can be further developed. At the development stage, actors bring ideas into a usable form or prepare the necessary settings for its use. At the diffusion stage, innovative offerings are deployed and deeply integrated into users' daily routines over time; and at the impact stage, the effects of adopted innovative offerings on users' ways of working and work efficiency become significant. This four-stage definition matches well with existing innovation process models. For example, Garud et al.'s (2013) model defines three stages of the innovation process (invention, development and implementation), and Myers and Marquis's (1969) definition divides the innovation process into idea development, problem solving and implementation.

However, the four-stage definition is not without issues. As Fichman et al. (2014, p.337) themselves point out, “this raises some interesting questions. If these stages are the same for digital innovations as they are for other kinds, then does this mean that digital innovation is not really a distinctive class of innovation in its nature or its effects?” Although they try to resolve this issue by identifying distinctive characteristics of information technology, such as “Moore’s Law, digitalization, and network effects”, these are insufficient to explain “how digital innovations are distinctive as a subclass of innovation” (Fichman et al., 2014, p.337). In particular, these characteristics do not distinguish digital innovation from conventional innovation that also involve digital technology. A clear distinction holds the key to justifying the legitimacy of digital innovation as an independent field.

The root of this issue, as perhaps shown by the four-stage definition, lies in its continued reliance on the “organizational pull” and “technological push” views (Cooper and Zmud, 1990) that treat digital innovation mainly as an outcome. These views fail to pay sufficient attention to its “distributed nature” – the essence of digital innovation supporting and being supported by its “generativity” (Zittrain, 2006) and “sociomateriality” (Svahn et al., 2009). As discussed in the previous section, the distributed nature of digital innovation means that when human, material and digital components interact, it may emerge at any project stage and in any geographical location, be initiated by any actor, and cause unexpected chain reactions (Nambisan et al., 2017). This distributed nature requires less emphasis to be given to the force of “organizational pull” in the discovery and development stages and the force of “technological push” in the diffusion and impact stages. Instead, views of digital innovation as an outcome should be replaced with a stance that sees it as both the result and the basis of innovation (Hukal and Henfridsson, 2017). Furthermore, the generativity of digital technology is more than “a function of technology”, as the outcome depends largely on actors interacting with the technology (Bygstad, 2017, p.183). In this sense, the focus should be on actors’ interactions with digital technology, which capture distributed innovation opportunities while creating them, and vice versa.

Guided by the four-stage definition of the digital innovation process, and emphasizing the distributed nature of digital innovation, this thesis examines the whole process of digital innovation, from the generation of new ideas to the embodiment of new forms, the growth of new users and the emergence of new uses. Table 2.2 briefly describes the purpose of each study.

Table 2.2 Purposes of the four studies in this thesis.

Studies	Stages	Innovation	Distributed opportunities-informed research purposes
Chapter 3	Discovery	New idea	To understand how actors interact with the characteristics of digital technology to access and utilize distributed resources to generate and represent new ideas.
Chapter 4	Development	New form	To understand how actors take advantage of the characteristics of digital technology to give form to an idea in a way that further elevates the innovation novelty of the final product.
Chapter 5	Diffusion	New adoption	To understand how actors appropriate the characteristics of digital technology to make a digital innovation accepted by more users and entrenched in their daily lives.
Chapter 6	Impact	New use	To understand how actors interact with the characteristics of digital technology to attain more benefits that exceed the original plan of a given digital innovation.

CHAPTER 3 PAPER 1 – COMBINATORIAL REPRESENTATIONAL PRACTICE [1]

3.1 Introduction

Digital technology offers fertile ground for radical innovation. Its malleability enables immense scope and diversity in the outputs of design processes (Kallinikos et al., 2013, Henfridsson et al., 2014), while dramatic improvements in price/performance have made powerful design tools available to many designers (Yoo et al., 2010b, Boland et al., 2007). Yet, it is perhaps its ability to represent a new world, unknown to our current world, which is the most powerful feature here (cf. Nandhakumar et al., 2013). The focus of this paper is on representational practices enacted by designers drawing on this ability.

I conducted an in-depth case study (Gerring, 2007) to examine designers in TopTech (pseudonym), a Chinese pioneer in the entertainment business, as they designed a truly first digital theatre. I was struck by the flexibility with which they redesigned their representational practices as they brought forth the digital innovation. The data analysis helped me gradually to build evidence of how representational practices were "assembled" by being taken apart and reintegrated as the design process required new ways to represent the emerging design.

In this paper, I address the following research question: *How do designers assemble representational practices to generate radical digital innovations?* In response to this question, I formulate a new theoretical perspective on representational practice in radical digital innovation, in which I conceptualize how representational practice can be seen as a flow of recombination of what I call *representational practice components* (conception, creation, and use). I argue that digital technology enables designers to benefit from collective, plural, distributed, and fluid aspects of representational practices.

This study makes a number of contributions to the digital innovation literature. First, I highlight how the use of digital technology in representational practices decouples representational practice components (conception, creation, and use), which in turn enables combinatorial representational practice. Second, I explain how

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[1] Wang, G., Henfridsson, O. and Nandhakumar, J., 2016. How Do Designers Assemble Representational Practices to Generate Radical Digital Innovations?. In *Proceedings of ICIS 2016.*

combinatorial representational practice improves idea generation while facilitating idea communication, leading to the generation of radical digital innovations.

This paper is structured as follows. In the next section, I discuss the conceptual basis of this study. This is followed by a brief description of the research design and method in terms of case selection, data collection and analysis. I present the empirical findings with three vignettes illustrating the combinatorial representational practice and then provide an in-depth analysis of the vignettes, focusing on what makes the practice unique and how designers appropriate it to generate radical innovations. Finally, I discuss the implications for both theory and practice.

3.2 Conceptual Basis

3.2.1 The Challenge in the Design of Radical Innovations and the Role of Representational Practice

Radical innovations are a principal source for companies to achieve long-term success (Rothwell and Gardiner, 1985). They constantly challenge incumbent products in terms of technological functions (Cooper, 2000), consumption experiences (Gruner and Homburg, 2000), and social meanings (Verganti, 2013). Design is a process that feeds radical innovations by generating innovative ideas and developing them into usable forms (Kolko, 2015, Ulrich, 2011, Walsh, 1996).

However, designing radical innovations is challenging. As its qualifiers suggest, the notion of radical innovation implies something that “never existed before” (Yoo et al., 2006) or is “unprecedented” (Cooper, 2000). It follows that the process of designing a radical innovation may be ambiguous and ever-changing as the project progresses (Seidel, 2007, Slater et al., 2014). In addition, the design, especially of complex products, is a collective activity of designers with diverse backgrounds (Catmull, 2008, Bødker, 1998). This diversity may hamper collaboration (Walsh, 1996). In order to deal with such a challenge, a reference point is needed to coordinate the collective efforts. A representational practice offers such a reference point, helping to maintain a shared vision that is argued to be important for the success of product design (Nandhakumar et al., 2013, Buchenau and Suri, 2000).

3.2.2 Representational Practice Components

I define *representational practice* as designers’ recurring interactions with representational objects (e.g., stories, metaphors, sketches, blueprints, models and prototypes). There are essentially three components of representational practice: conception, creation and use.

First, *conception* means conceiving appropriate forms of representational objects with reference to ideas. A common view of representational objects is that they are "containers" of ideas (Bødker, 1998), indicating that it is the ideas rather than the objects themselves to which greater attention should be paid (Gero and Kannengiesser, 2012, Okhuysen and Bechky, 2009). Without embedded ideas, a representational object loses its reason for existence. The purpose of representational objects is to express the ideas embedded in them. For example, when a designer draws an idea on a napkin and passes it to a colleague to explain it, it is the idea rather than the napkin that matters in that situation. The napkin can be replaced by an iPad application, the back of a business card, a table top, or even the ground. Anything on which the designer can draw an idea can be a representational object of the idea. However, none of them without the idea is a representational object. Yet, although major attention must be paid to ideas, the forms of representational objects are also important, since these affect the efficiency and effectivity of representational practices (Vriens et al., 1998). Hence, in the conception of a representational practice, it is also critical to consider available forms of representational objects and pick one that can convey the idea most effectively and efficiently.

Second, *creation* means translating ideas into representational objects. This is the actual movement of ideas from the conceptual to the material world. The literature provides numerous examples of creation in various kinds of design practices. For example, Troiani and Carless (2015) examine creation in the form of collaging, sketching and photography in architectural design; Schenk (2014) describes sketching and annotating in graphic design; Seidel and O'Mahony (2014) offer storytelling, metaphorizing and prototyping as creations of representational objects in product design; and Sarkkinen and Karsten (2005) present planning, charting, annotating and gesturing in task design.

Third, *use* means reading ideas from representational objects. The work of Ewenstein and Whyte (2009) illustrates three different uses of representational objects. First, concrete and stable representational objects can be used as a common ground for idea communication and standardization. For example, Bergman et al. (2007) describe the use of proto-architectures and project plans to unify activities of diverse designers. Second, representational objects that are relatively abstract and in flux can be used as epistemic objects of inquiry in the pursuit of new knowledge. For example, Bødker and Grønbæk (1991) depict the use of municipal prototypes for designers' idea exploration. Third, fixed and taken-for-granted representational objects can be used as technical objects offering instruments and reference points on which subsequent designs can build. For example, Ewenstein and Whyte (2009) describe the use of a plan of an under-floor structure as a reference point for architects to design beams under the roof. Similar concepts include the "talking sketches", "thinking sketches" and "storying sketches" in van der Lugt's (2005, p.102-108) study of sketching in design.

In my view, all three components described above are indispensable aspects of representational practice. Representational practice loses its purpose without conception, has no objects to work on without creation, and cannot fulfil its duty without use.

Given this theoretical background, I set out to develop a new perspective on representational practice which I call "combinatorial representational practice". I conducted an in-depth case study of a digital theatre design project to investigate how digital technology enables combinatorial representational practice, how designers actually conduct combinatorial representational practice, and how combinatorial representational practice leads to radical digital innovations.

3.3 Research Approach

3.3.1 Case Selection

Big Globe | Small Globe | Motion Seats | Dome Screen

Figure 3.1 TopTech's digital theatre.

TopTech is a Chinese pioneer in the entertainment industry. The company originated in the media center of a Chinese public university in 1998 and was then spun off and privatized in 2005. At the time of this study, the company had more than 300 employees. Reflecting its business success, the company has received numerous awards from Chinese governmental authorities and industry associations. The empirical focus was on TopTech's self-developed digital theatre (see Figure 3.1).

The project was selected for a number of reasons. First, the digital theatre is radically innovative. The development of the digital theatre generated no fewer than 30 patents. It offers unprecedented customer benefits, substantial cost reductions, and the ability to create new businesses (Slater et al., 2014). For individual clients, the digital theatre is "doing what we did not do before" (Norman and Verganti, 2014, p.82) by providing audiences with immersive 3D experiences without using 3D glasses. For institutional clients, the digital theatre is much cheaper and its construction time much shorter than competitor products. Furthermore, as its building is designed to be decomposable, the digital theatre is highly reusable. With its reusability and a variety of original software, TopTech developed a new business model that did not previously exist.

Second, TopTech designed a full range of content (digital animations), software and hardware of the digital theatre. Hence, I believe that this project offers sufficient data to provide an in-depth understanding of the design of radical digital innovations.

Finally, I was able to gain unprecedented access to TopTech's headquarters and to build ongoing relationships with key project members in order to collect rich field data, including access to classified project documents.

3.3.2 Data Collection

The main data collection phase ran from June 2015 to February 2016. I collected archival, observational, and interview data.

First, I collected both digital and paper-based archival data in order to obtain accurate and detailed information about early stages of the project. I accessed technical documentation and patent specifications with the help of TopTech's personnel. I also collected other documents, such as TopTech's prospectus, house journal, business magazines and online articles.

Second, I undertook two rounds of observation. The first took place in June 2015 (48 hours), and the second ran between December 2015 and February 2016 (252 hours). Observations took place primarily at TopTech's headquarters, but also at customer companies' premises and trade fairs. I attended project meetings and observed the implementation and use of the digital theatre, as well as the development of new content for the digital theatre. Observational data were recorded in the form of field notes and photographs. The focus of observation was on activities, events, and choices

(Langley, 1999) relating to the design of new content and functional upgrades to the digital theatre.

Finally, I also conducted 41 semi-structured interviews with 43 interviewees. In order to gain a cross-sectional view, the interviewees were drawn from different departments and management levels. Each interview lasted between 20 and 90 minutes and was voice-recorded where permission was granted by the interviewees. Formal interviews were complemented by informal conversations with project members in the context of day-to-day observations. Follow-up interviews were conducted after the main phase of data collection, usually with the intention of clarifying events and confirming findings. In the following sections, all interview quotations have been translated from Chinese.

3.3.3 Data Analysis

The data analysis commenced as soon as the data collection began. Throughout the analysis process, there was constant comparison 1) between archival, observational, and interview data, 2) between different managerial levels, and 3) between previously- and newly-collected data. For instance, as far as possible, I used archival and observational data to complement and triangulate interview data. During the analysis, I also frequently revisited the research site to ask interviewees for comments on my interpretations. Their comments either verified the interpretations or revealed new findings. This iterative movement between data analysis and data collection allowed us to continuously improve the quality of my interpretations. Specifically, my data analysis was an iterative process that followed four steps (see Table 3.1).

Table 3.1 In-depth data analysis.

Stages	Tasks	Outputs
1. Coding key events	a. Identify key product concepts b. Identify key events c. Establish a timeline of the events	A chronology of key events (Figure 3.2)
2. Coding representational practices	a. Identify representational practices b. Extract representational practice components	Examples of representational practices in key events (Table 3.2), and three vignettes
3. Coding and clustering of concepts	a. Develop descriptive coding b. Identify first-order categories c. Group the categories d. Define second-order themes	Two effects of combinatorial representational practice
4. Developing a process model	a. Define constructs for model building b. Analyze interplay between constructs	A process model of combinatorial representational practice (Figure 3.4)

First, I conducted open coding to identify key events. While many events took place, in the analysis, I focused on those relating to the development of key product concepts. This is because the generation of radical digital innovations was an essential part of my research question, and because new ideas are the source of innovations (Ende et al., 2015, Nicholas et al., 2015). I then established a timeline of key events based on this coding procedure (see Figure 3.2).

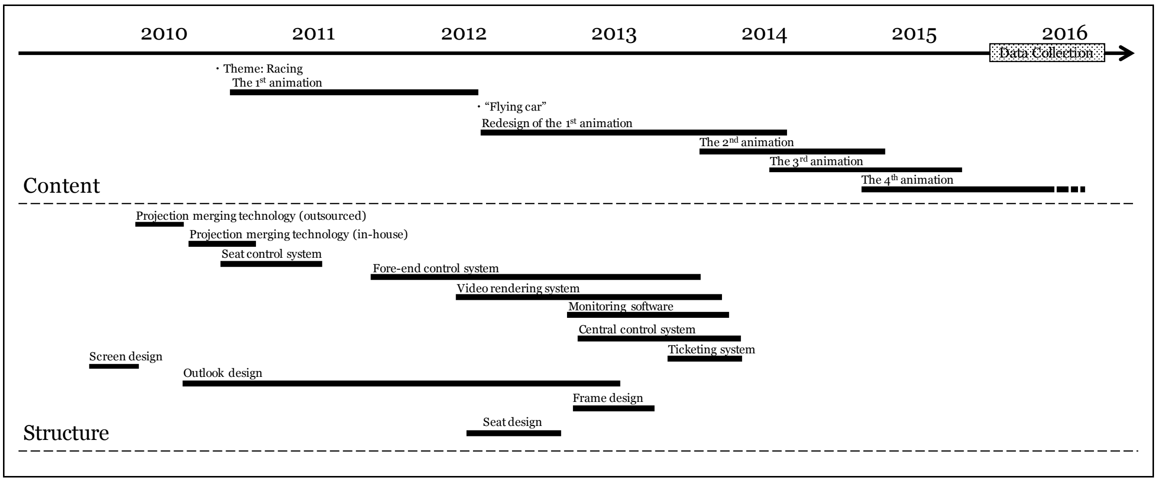


Figure 3.2 A chronology of key events

In the second step, since representational practices were another essential part of my research question, I identified extracts relating to representational practices in the field materials collected for each event. Having highlighted the extracts, I broke each extract down in terms of conception, creation and use in order to depict clearly what these three components looked like in practice, how they interplayed with each other, and how they jointly formed a representational practice. I visualized representational practices in terms of actors, actions, and outputs (see, for example, "Analyzing the Three Vignettes" in Table 3.2) as a data display (Miles et al., 2013). In order to visualize in more detail how the designers organized representational practices, this paper adopts the form of vignettes (cf., Vaast and Levina, 2006, Carlile, 2002, Nandhakumar et al., 2013) in the following section.

The next stage of coding identified first-order categories focusing on how the designers embodied an idea. I was able to identify four major groupings of actions: intersection, triangulation, reinterpretation, and invention. Intersection means taking common information and aspects from various representational objects in order to depict a sharper, more multi-faceted image of an idea; triangulation means using diverse information and aspects from multiple representational objects to confirm that an understanding of an idea is correct; reinterpretation endows given representational objects with new meaning; and invention means discovering new ideas by ignoring given representational objects or shifting the focus from a more relevant aspect to other, apparently less relevant aspects of the objects. In the final stage of coding, I clustered the categories according to whether the actions clarified or expanded the idea. Two identified groupings were cohesive effect and serendipitous effect. A *cohesive effect* improves the clarity of the leading idea and the coherence of project members' shared understandings of the idea, while a *serendipitous effect* denotes the emergence of valuable new ideas through accidental discoveries.

3.4 The Digital Theatre and Its Design Processes

3.4.1 Two Parts of the Digital Theatre: Structure and Content

TopTech developed two versions of the digital theatre: one was referred to as "big globe", and the other as "small globe" (see Figure 3.1). The big globe was for outdoor use (e.g., theme parks) and the small globe for indoor use (e.g., shopping malls and trade shows). Whether large or small, the digital theatre consisted of two parts, which the company called "structure" and "content". The "structure" included the software and hardware that enabled the provision of content, while the "content" referred to digital animations.

More specifically, structure included the physical building, projectors, seats, computer and other computer-controlled devices, such as fans, lighting and stereo equipment for rendering atmosphere. Similar to conventional movie theatres, the globe also had projectors, a screen, and seats. However, it was very different from conventional theatres in that its screen was huge and semi-spherical. In addition, multiple projectors were used to project a complete image that covered the whole semi-spherical screen in order to provide good image quality. At the center, inside the building, there was a huge stage carrying power-driven auto kinetic seats. Under the stage were mechanical devices that controlled the movement of the seats (e.g., vibration, inclination and oscillation). Because multiple projectors were used in combination to project animations, specialized software was needed to coordinate the projectors so that the separately-projected images could be integrated into a seamless and harmonized whole. TopTech also developed software to coordinate the seats, fans, lighting, audio and other equipment to offer an integrated experience. In addition, a monitoring system was developed for real-time surveillance of the daily operations of sold and leased digital theatres.

At the time of this study, TopTech had finished the design of the structure of both big and small globes and produced three animations, while new animations were continuously being produced to attract new visitors.

3.4.2 Design Process of the Content

Since the inception of the digital theatre project, the management team had been making full use of their core competences acquired through their previous experiences of the animation business. They believed that content (i.e., digital animations) was always the most important part of an entertainment business. For this reason, although the project was to create a novel digital theatre, it started the development of an animation very early.

When they commenced the design of the first animation, TopTech management devised an initial product description for the animation as “the animation should offer an exciting experience”. The keyword often used to refer to the nature of this product was “exciting”. Similar keywords also used to describe the expected final product included “impressive”, “extreme”, “wow” and “surprising”. These keywords also became an essential part of key ideas in the design of the digital theatre’s exterior and interior. All these keywords were about how audiences should feel and what they should experience as they watched the animation. The keywords generally originated from the CEO, who usually determined the themes and genres of all animations and the feelings and experiences that the animations should convey to audiences. The CEO then presented his ideas and discussed them with key staff (e.g., experienced directors, designers and project managers). In these discussions, they talked mainly about whether the ideas were technologically feasible and whether consumers would like them. If most key staff supported an idea, the project would progress forward; otherwise, the idea would be abandoned.

Having determined the main ideas, a chief director was appointed to develop a fully-fledged story. Meanwhile, a chief project manager was appointed to estimate time, financial and human costs, to create a detailed project schedule, and to organize a project team. Once the project team had been established, a standard animation production process was adopted, from “script” phase to “final touches and musical score” phase (cf., “Pixar’s Animation Process”, 2016). The chief director and chief project manager jointly managed the project, each playing different roles: the chief director was in charge of animation quality, while the chief project manager was in charge of the project schedule. Several assistant directors and sub-project managers were also appointed. An assistant director and a subproject manager worked in pairs during each phase to manage the animation quality and the schedule respectively.

3.4.3 Design Process of the Structure

After deciding on the theme for the first animation, and while they were halfway through the development of the animation, they started to design the structure of the digital theatre. They began by designing the building's exterior and interior (e.g., wall, roof and seats).

The design started with the CEO's doodles. As an engineering designer in the Entertainment Experience Design Center recalled:

> *It was a Saturday. During the morning of that day, I was working overtime in the company with Joey [a project manager] and another guy who was doing 3D modeling. I unexpectedly received an email from Sean [the CEO]. He's on a business trip ... Along with the email, there's a freehand doodle of his initial idea of the exterior and interior of the digital theatre. Later, he phoned me and explained his idea.*

The engineering designer, project manager, and 3D staff sat together, discussed how to enrich the doodle, and developed a 3D model with 3ds Max (design software). They created a chat group on WeChat (a mobile text and voice-messaging service) for discussion and invited the CEO to the group, updating him on progress with the working sketch. The staff sent pictures of their 3D model to the CEO, who gave very specific and detailed comments on it, such as the shapes of joints between components of the exterior shell and its reflective material. The staff then modified it based on his comments and sent him new versions. There would then be further comments from the CEO. Sometimes, the CEO sent new doodles; sometimes, there were merely text or voice messages. This back-and-forth continued until midnight, when the CEO and staff finally agreed on an initial version of the design of the structure.

3.5 Assembling Representational Practices

Communication of ideas was a major challenge in the digital theatre project. For example, although the scriptwriters had a clear idea in their minds of what a character should look like, they found it very challenging to describe all the details to concept artists. It was especially difficult to communicate what feelings a constituent part of the animation (e.g., the appearance of a building or the visual effect of a car crash) was intended to convey. This was because it was difficult to choose a precise vocabulary to describe the desired feelings and to ensure that project members interpreted the same word in the same way.

In order to deal with this challenge, the designers sought to assemble representational practices. However, although its main purpose was to facilitate communication of ideas, assembling representational practices also resulted in the emergence of new ideas or, in other words, improvements in idea generation. In this section, I outline three vignettes illustrating the moment that three ideas emerged as the designers assembled representational practices to facilitate idea communication.

3.5.1 Vignette 1. Emergence of "Flying Car" in the Design of the Content

In the development of the first animation, the CEO told a director of the Multimedia Development Department that he wanted something "exciting". He wanted an animation that would wow audiences. However, the director and other staff found this description of the key animation idea too vague. Having failed to communicate his ideas to the director, the CEO went back to his office and started to search online for related information, such as blogs, reports, images, and videos. He searched on Baidu (a web search engine) with the keywords "exciting", "impressive", "extreme" and "surprising". He then picked the search results that were closest to his ideas.

A few days later, the CEO brought a collection of the search results to the director. With the aid of the blogs, reports, images, and videos, he again explained his ideas to the director. During this explanation, the director asked questions and rephrased the CEO's words to confirm that he had understood the ideas correctly. The director also challenged the CEO's arguments. For example, he asked whether a picture of a ballet show conveyed more of a feeling of elegant, exotic or unacquainted. During these discussions, they usually came up with new ideas and then searched for more materials online with new keywords. In doing this iteratively, they gradually realized that the results most attractive to them were Formula 1 racing, extreme skateboarding, bungee jumping, action movies, and roller coasters. Thus, they narrowed their focus to these.

They then involved other staff in intensive discussions about why these results were most related to the keywords and what characteristics they had in common. New findings and ideas kept emerging during the conversation. For example, they later found that car racing itself was too ordinary, and that it might be more exciting to combine it with aircraft and to imitate the movement of roller coasters. As a result, they arrived at an idea, "Flying Car". Figure 3.3 (from their documentary video) shows a snapshot in which early members of the project are discussing the product idea.

Figure 3.3 Project members are discussing product concepts

3.5.2 Vignette 2. Emergence of “Heavy-Metal” in the Design of the Content

The company also devised an organizational-level solution to deal with the challenge of communicating design ideas effectively by establishing a dedicated sketcher team. The sketchers helped project members who were incapable of drawing to draw their ideas. When a staff needed to draw a picture, s/he went to the team and approached an available sketcher. S/he then sat with and explained the idea to the sketcher, and the sketcher started to draw it. While the sketcher drew, s/he watched the progress and gave suggestions in real time. The following is an observation of the emergence of a key idea, “heavy-metal” (a design evoking a feeling of harsh-sounding rock music), of an animation under development.

A scriptwriter and a sketcher were looking at a computer screen. The sketcher was drawing a vehicle. It looked like a sports car but had a pair of wings. The scriptwriter was giving real-time suggestions to the sketcher, such as “Draw a perfect circle here …” and “Hummm… here and here, the line is too thin …”, and asking for the sketcher’s suggestions, such as “Yellow or blue? Which one do you think is better?” When the sketcher mistakenly drew a hard outline for a part of the car, the scriptwriter said, “Wait, wait … I like this. Doesn’t it look ‘heavy-metal’?”

According to a follow-up interview with the scriptwriter, “streamlined” was his initial idea for the design; however, he changed his mind after he saw the hard outline and decided to replace “streamlined” with “heavy-metal” as a guiding idea to modify previous designs and conceive subsequent designs.

3.5.3 Vignette 3. Emergence of “Futuristic” in the Design of the Structure

“Cool” was one of the key ideas of the building design. The following retrospective comments are from two early members of the theatre-building design team (the project manager and engineering designer mentioned above in the “Design Process of the Structure” section). Their comments show how all modeling activities stuck to the leading idea of "cool", which also led to the emergence of a new idea, "futuristic" (a design evoking a feeling of high tech).

When asked about the birth of the building design, the project manager recalled:

> *In the beginning, Sean [the CEO] asked us to draw a smooth surface to make the exterior shell look like a perfect ball. We did it. But, we [the project manager, engineering designer, and 3D staff] thought it looked very bizarre. ... We sent it to Sean and told him honestly what we thought. Along with it, we also attached an alternative design using hexagonal plates [see the image of a big globe in Figure 3.1]. The hexagonal-plate version looked more like a space capsule, which we believed was closer to Sean's initial idea that "the product must look cool and visually spectacular".*

Recalling the back-and-forth communication of the 3D modeling process, the engineering designer said:

> *I think he [the CEO] just did not care about every detail of the model, such as how to route the wires of the electric power system. He checked mainly the overall visual effect of its exterior and interior appearance from a customer's point of view. ... For example, at the beginning, we wanted to use steel tubes for the frame. But, Sean [the CEO] insisted on trying aluminium tubes because steel did not look as "cool" as he wanted. So, we followed his idea, and we found that aluminium, especially its reflection, actually looked very nice. It looked very "futuristic".*

As such, "futuristic" became a key idea for subsequent designs.

3.6 Analysis of the Three Vignettes

Table 3.2 summarizes key information about the three vignettes in terms of representational practice components.

In Vignette 1, the representational practice to clarify the idea of "exciting" was a combination of three components: 1) the conception by the CEO that generated "exciting" and an initiative to verbalize and visualize the idea; 2) the creation by anonymous creators who generated diverse representational objects somewhat relevant to the idea; and 3) the use by the CEO and other project members who detected and tapped into the inner bond between the objects.

In Vignette 2, the representational practice to clarify the idea of a “streamlined car” was also a combination of three components: 1) the conception by the scriptwriter that generated a mental image of a “streamlined car” and an initiative to express the idea in the form of drawings; 2) the creation by the sketcher who drew sketches; and 3) the use by the scriptwriter who experimented with alternative visual effects and appropriated accidental discoveries.

Table 3.2 Analysis of the three vignettes

Vignettes	Representational Practices			
	Components	Actors	Actions	Outputs
1. Representing the idea “exciting”	Conception	CEO	Conceiving ideas Conceiving forms	An idea of “exciting” Using online visual and verbal materials
	Creation	Anonymous actors	Photographing Shooting Narrating	Pictures Videos Blogs and reports
	Use	CEO, the chief director, other project members	Reading a collection of blogs, reports, images and videos	An idea of “flying car”
2. Representing the idea of a car for a new animation	Conception	Scriptwriter	Conceiving ideas Conceiving forms	An idea of “car” and “streamlined” Using sketches
	Creation	Sketcher	Sketching	Sketches
	Use	Scriptwriter	Reflecting on a mistake Experimenting with new shapes, lines, and colours	An idea of “heavy-metal”
3. Representing the idea of the building frame	Conception	CEO	Conceiving ideas Conceiving forms	An idea of “cool” building Using 3D models
	Creation	3D modeller	Modeling	3D models
	Use	CEO, engineering designer, project manager, 3D modeller	Reflecting on 3D models	An idea of “futuristic”

In Vignette 3, the representational practice to clarify the idea of a “cool” building consisted of three components: 1) the conception by the CEO who generated a mental image of a “cool” building and an initiative to express the idea in the form of 3D models; 2) the creation by the staff who generated 3D models; and 3) the use by the CEO and the staff who studied the aesthetic meanings of the two metal materials and came up with the idea of “futuristic”.

The rest of this section analyzes the three vignettes in detail.

3.6.1 Digital Technology-Enabled Loose Coupling between Representational Practice Components

The three vignettes show that digital technology enables a loose coupling between representational practice components (i.e., conception, creation and use). As a result, conception and creation may be divided between different actors, creation may not foresee how its output will be used, and use may not abide by the original conception.

In Vignette 1, the CEO conceived the initial idea and randomly collected a set of online materials to represent his idea. The collected online materials were heterogeneous, including a large number of blogs, reports, images, and videos. The heterogeneous materials used as representational objects in this project were not created by the CEO but by many anonymous creators (i.e., online users), who might be unaware of the existence of the digital theatre project and created the objects for other projects. Even so, their creation of the objects without considering the project goal served this project well. This was because the randomly-collected objects were not really randomly organized, but bound by a common keyword, “exciting”, which was an essential part of the product idea. The bond between the objects was created by the creation process, as anonymous creators embedded the idea “exciting” into the objects. Although their creation happened at different times, in different places and for different tasks, part, if not all, of their purpose was to represent the idea “exciting”. This inner bond was used by the online database in the form of keywords to index the heterogeneous objects.

Baidu (web search engine) allowed heterogeneous materials to be retrieved through the same keyword in the online database. It returned various forms of online objects indexed by the keyword “exciting”. However, these objects related to the CEO’s representational purpose, not to a project goal shared between him and the creators. The only bond between the objects was the keyword. Their relevance to the project goal was enacted as the CEO identified and tapped into the bond and related it to the project goal. As such, the search engine maintained the bond and enabled the CEO to appropriate it and thus to appropriate the creation component of other projects’ representational practices in his own representational practice.

Put simply, in this representational practice, the project goal was mostly on the side of the CEO rather than the side of the anonymous online users. In this sense, with data homogenization, digital technology enables the loose coupling between representational practice components by relaxing the restriction of project goals.

In Vignette 2, the conception was conducted by the scriptwriter, who had an initial mental image of the expected sketch of a "streamlined car" before turning to the sketcher for help. Rather than conceiving the sketch, the sketcher was responsible for following the instructions of the scriptwriter. Although the sketcher might also have had some conception of how the sketch should be drawn, his conception had to abide by the scriptwriter's conception and needed the scriptwriter's judgment. The sketcher played a comparatively minor role in the conception part, and his role was limited mainly to the creation of the sketch. However, the scriptwriter had no drawing skills and had little to do with the creation part. In other words, in this co-sketching, the scriptwriter acted as the brain, while the sketcher was the hand. This representational practice, which relied on real-time instructions, was possible because of the flexibility of the drawing software. The software reduced the sketcher's time and the cost of modification, which relieved the scriptwriter's concern about the sketcher's tolerance of frequent changes in requirements. Working on both sides, to increase the sketcher's tolerance of changes and reassure the scriptwriter that he could ask for changes, the drawing software enabled the two actors to undertake different component parts of the representational practice and conduct it jointly.

Similarly, in Vignette 3 of the co-modeling, although the collaboration between the CEO and staff was not as intimate as that in the co-sketching owing to their physical distance, the back-and-forth communication mediated by WeChat also demonstrated a separation between the conception and creation of the modeling. In the co-modeling, the CEO conceived the initial idea, the staff created 3D models according to his requirements, and the CEO then evaluated the models and asked for further changes. The staff also proactively created models that were not specified, even though they knew that the CEO might ask for changes or reject them, which also exemplifies how the software increased the staff's tolerance of changes.

In summary, in these two representational practices, the drawing and modeling software made it easier to deal with frequent changes to requirements, which enabled the conception and creation of the sketches and models to be conducted separately by different actors. In this sense, with its flexibility, digital technology enables the loose coupling between representational practice components by increasing tolerance of changes.

3.6.2 Cohesive Effect

The vignettes reveal that the designers appropriated the loose coupling between representational practice components by assembling the required components to form a representational practice to serve their own representational purposes. This representational practice led to increasing clarity on the initial ideas.

In Vignette 1, the CEO only picked blogs, reports, pictures and videos that were coherent with his idea. As he assembled the search results, he was focusing on how to make his idea clearer, rather than looking for other ideas. For example, the search results for “exciting” brought up diverse materials, including not only car racing but also Korean dances, facial expressions, cartoons, and animals. As one of the main concepts was “car racing”, most other materials were judged to be irrelevant and abandoned.

Control over the coherence of the selected online materials was also possible because the materials expressed the idea in different ways and from different angles. These various ways and angles introduced by the combination of relevant online examples enabled intersection and triangulation between them.

Each online material was merely one of many possible instances of the idea. The large volume of the collected online materials resulted in overlaps between them, which provided rich, coherent information to understand the idea to which their common parts referred. For example, each blog, report, picture and video of car racing and roller coasters was an example of “exciting” in itself; however, none alone could define what “exciting” was. The reason is obvious. It is reasonable to say, “riding a roller coaster is exciting”, whereas it is absurd to say, “exciting is riding a roller coaster”. Only when they were appreciated together were project members able to infer that the “exciting” was what they had in common.

In addition, materials that were appreciated later also served to verify understandings of a leading idea achieved from the materials appreciated earlier. Since the later materials might express the idea in different ways and from diverse angles, appreciation with the different ways and angles also enabled triangulation between the diverse materials to verify and clarify the idea. In this way, the result (the understanding of the idea) arising from this inference and verification of the commonality of diverse materials gradually became coherent as the volume of collected materials increased.

In Vignette 2, as the scriptwriter's words showed (e.g., "Draw a perfect circle here"), his instructions were subject to his mental image. The sketcher's drawing that followed the instructions was thus also subject to the mental image. As such, the co-sketched drawings became increasingly close to the scriptwriter's idea and eventually embodied the idea accurately. This increasingly high coherence was possible due to the physical proximity of scriptwriter and sketcher. It enabled real-time and frequent interactions.

On the one hand, the interactions enabled the sketcher repeatedly to ask the scriptwriter questions to verify his understanding of the idea. The increasing volume of answers from the scriptwriter explained the same idea using different expressions. By inferring overlapping information between the expressions, the sketcher was able to clarify his understanding. On the other hand, the interactions enabled the scriptwriter to appreciate how his idea could be expressed in different ways, either by conceiving answers to the sketcher's questions or by learning how the sketcher rephrased his ideas.

In addition, even if the sketcher had a clear understanding of the idea, he often had to find and choose appropriate drawing tools available in the software. Although the sketcher was familiar with almost all of these tools, he often needed to try them before finally deciding on the most appropriate choice. By watching the drawing, the scriptwriter observed this tool-selection process, which showed him other options that could be used to embody his idea. As the questions, answers and various equivalent visual embodiments gradually increased, more information was available for intersection and triangulation that led to a coherent understanding of the initial idea.

In Vignette 3, similarly to the co-sketching situation, the CEO described his idea to the staff. The staff were able to ask questions in order to confirm their understanding of the idea. Through back-and-forth communication, the CEO was able to evaluate the models by comparing them with his initial idea. His feedback provided the staff with more information to clarify and refine their understandings of the idea. As more coherent understandings were confirmed and less coherent ones removed, the outline of the idea became increasingly clear and concrete to the staff, which led to a more accurate model. In addition, since the discussion between the CEO and staff was mediated by models that were fixed and concrete at the scene, the staff were able to see how the CEO actually evaluated the models and to infer his specific requirements from his comments.

These vignettes show digital technology brings designers and their works to the same place. Works of actors with various backgrounds introduce a large volume of heterogeneous representational practices of which designers are able to take advantage. Tapping into such heterogeneity, designers become versatile in defining an idea with prolific information and from various aspects. Of course, the incorporation of less relevant, heterogeneous materials may also blur the image of an idea. This problem is controlled since the actor's choice is regulated by the initial idea. Part or all of the chosen representational practice components should always be relevant to the initial idea if they are to be used to form a concrete design. Under the guidance of the initial idea, each actor's representational practice aims to elicit the intersected part of the information in order to infer the initial idea inductively and to verify extant understandings through new and diverse information.

In short, in assembling representational practice components, designers conduct intersection and triangulation, which ensures that the introduction of new information and the reading of past information adhere to the leading idea. Hence, I name this effect, the *cohesive effect*.

3.6.3 Serendipitous Effect

The vignettes also reveal that assembling representational practice components leads to the emergence of new ideas. In Vignette 1, as mentioned above, the search of heterogeneous materials required a fixed format of information cue - textual keywords. Hence, the CEO had to translate his initial intent into the required format. The translation was a process that excluded other auxiliary information and narrowed the focus to the most critical part of the original idea, reducing the richness of information that might be used to describe the idea. Since the heterogeneous materials were organized by keywords rather than the project goal at hand, and because the keywords were only a part of the whole goal, less relevant materials were always mixed in with the search results. Even if the keywords had been able to depict the whole goal, the search might still have returned some results that poorly matched the search goal, as keyword-based automated search engines inevitably return low-quality matches (Brin and Page, 2012).

Furthermore, while the CEO was looking for online materials to represent "precision manufacturing" (a requirement that all car parts should be designed with extreme accuracy), he collected pictures of motorbikes, cars, and aircraft. He used red circles to highlight the area of engines in the pictures and typed "precision manufacturing” in Chinese alongside the circles. However, other parts of the pictures outside the circles were retained when the pictures were presented to other project members, even the peripheral parts were not closely related to the idea of “precision manufacturing”. These parts provided extra information in terms of representing “precision manufacturing”. As such, the combination of the materials introduced less relevant extra information.

Shifting the focus to or being inspired by such information, project members encountered new discoveries and interpreted earlier and later materials in different ways, which led to the emergence of ideas beyond the scope of the work at hand. For example, when the project members used “exciting” and “car” as keywords in a later search, the search results also included photos of real-world aircraft and pictures of comic vehicles. As materials of cars and aircraft were frequently shown together, the project members became curious about and started to study the link between “exciting” and “flying” experiences, which eventually led them to invent the new theme of “flying car”.

Vignette 2 shows that the co-sketching, relying on the flexibility of digital technology, allowed the goal of the drawing to be changed during the drawing process. Its initial goal was supposed to visualize what was in the mind of the scriptwriter. As a result of increased tolerance of changes, the scriptwriter appropriated the co-sketching for other purposes, such as asking the sketcher to try alternative lines, colours, and shapes for car parts to explore a more suitable visual effect.

In addition to active exploration, there was also passive exploration. As previously mentioned, there was a tool-selection process in the sketcher’s drawing. This process showed the scriptwriter not only more ways to embody the idea, but also new visual effects beyond his existing knowledge. Since the scriptwriter was not an expert in drawing, his knowledge was limited to his past experience. Hence, there were many visual effects with which he was unfamiliar. By watching the tool-selection process, the scriptwriter encountered new visual effects that were potentially more to his taste.

There is also usually a trial-and-error process in novel design tasks (Cross, 2004). In TopTech, the dedicated sketcher team was set up to help ideators, who were usually trying to initiate a new project, often in pursuit of high levels of novelty. As the co-sketching vignette shows, a sketcher might misunderstand what a colleague seeking his help was saying or make technological mistakes, even when the colleague described the ideas clearly. However, although the mistakes were undesirable in terms of expressing the initial idea, they sometimes led to useful discoveries. For example, when the sketcher drew hard lines by mistake, the scriptwriter interpreted the design as "heavy-metal" and replaced his initial idea of "streamlined" with this new idea.

Vignette 3 shows that physical and temporal separation also meant that the staff sometimes could not get timely and sufficient answers, although they were able to ask further questions to clarify their understandings. Hence, in some situations, the staff had to guess what the CEO actually wanted when creating the models. Their guesses might introduce information that was less coherent with the initial idea, which might be appropriated for new discoveries. For example, the CEO had not considered the frame tube material, and only realized its necessity after the material had been chosen. It was only after the choice of frame tube material was incorporated into the model for discussion that he realized the necessity of the choice. Because he had not specified the material, two materials were tried, which revealed conflicting preferences between the CEO and staff. They started to study the differences between steel and aluminium. However, rather than the physical properties, they focused more on the aesthetic meanings of the two materials. They concluded that aluminium looked better, and interpreted the unique feeling aroused by the visual effect of the aluminium frame as "futuristic" (the appearance of aluminium suggested buildings in science-fiction movies to them). "Futuristic" became a basic idea for subsequent design work. In addition, the staff even actively created and proposed new designs that the CEO did not ask for, which also introduced new information that broadened his horizons for the further conception of the theatre building.

In short, assembling representational practice components incorporates less relevant extra information and angles. In studying the new information and angles, designers engage in either reinterpretation or invention, which results in serendipitous opportunities to make new meanings expanding the initial idea or to generate new ideas. Hence, I name this effect, the *serendipitous effect*.

3.7 Discussion and Implications

In response to the research question, the above analysis reveals that digital technology enables a loose coupling between representational practice components. This loose coupling enables designers to assemble representational practice components to serve their own representational purposes, rather than carrying out all three components by themselves.

Data Homogenization-Enabled Loose Coupling. This study has shown that the data homogenization of digital technology relaxes the restriction of project goals. Data homogenization (Shannon and Weaver, 1949) is a fundamental property of digital technology, allowing heterogeneous data to be organized in the same binary-digit format (Yoo, 2013, Yoo et al., 2010b). By appropriating this property, online databases index heterogeneous materials, and web search engines retrieve the materials with textual keywords (Brin and Page, 2012). Since keywords indicate internal connections between materials in terms of what information they relate to, the keyword-based organization of online materials makes it easier for designers to identify relevant materials. Because the materials are bound by keywords rather than a fixed project goal, designers are able to adopt representational objects created for other purposes without offending their own project goal, as long as the keywords are an essential part of the product ideas of the project.

Flexibility-Enabled Loose Coupling. This study has shown that the flexibility of digital technology increases tolerance of changes. The focus of digital technology (sketching and 3D modeling software) is often on increasing drawing productivity (Jonson, 2005), endowing designers with the flexibility to revisit and change their drawings swiftly and more easily. This improvement allows representational practice components to be conducted by different actors. Although it is not new that an ideator can specify requirements and then a creator translate it into other forms in design practices, the extant literature rarely mentions that an ideator may intervene in the creation process in real time and give very detailed suggestions (e.g., "Can you make this edge sharper?" and "I want this part round" in the co-sketching), as witnessed in this study.

The above analysis also reveals that assembling heterogeneous representational practice components results in both a cohesive effect that improves the clarity of an initial idea and a serendipitous effect that increases the emergence of new ideas.

Assembling Representational Practice Components and the Cohesive Effect. A coherent understanding of a leading idea is critical in guiding design decisions (Goldschmidt and Sever, 2011, Mamykina et al., 2002). Representational practice serves this purpose by offering a shared reference point in the form of representational objects, for example, the "concept book" in Nandhakumar et al.'s (2013) study. However, researchers (e.g., Stiny, 1980) assert that designers may see different meanings in the same object, which may inhibit a coherent interpretation of the object.

This study shows that coherence can be maintained through careful evaluation of the relevance of representational objects to the leading idea. The study further shows that assembling representational practice components introduces a range of diverse information and angles that overlap in referring to the same idea. This diversity enables the leading idea to be instantiated in diverse ways. Searching for intersections of these diverse instantiations increases the richness of materials, leading to a more comprehensive understanding of the leading idea. In addition, designers may also triangulate to check their understandings with different information and angles. Through such intersection and triangulation, designers can make an initial idea increasingly clear.

Assembling Representational Practice Components and the Serendipitous Effect. Serendipity is a critical source of radical innovations (de Rond, 2014), manifesting as new and unexpected combinations of existing knowledge and new information (Goldschmidt and Sever, 2011), which are often achieved through accidental encounters (Austin et al., 2012). Similarly, in proposing their idea of "design attitude", Boland and Collopy (2004) argue that better options are often achieved by going beyond default solutions and pursuing new possibilities for the future. Henfridsson and Yoo (2014) also note that it is common in creating new innovation trajectories that inventors detach themselves from existing choices to invite opportunities to further their design visions. Cross (2004) writes that a creative design seems more likely to arise when designers have a conflict to be resolved between high-level problem goals. In addition to the critical role of serendipity in the generation of new ideas, this study further shows how assembling representational practice components realizes serendipity. It reveals that the introduction of heterogeneous information and angles inevitably incorporates extra information and angles that are less relevant to the project goal, which bring about accidental discoveries that designers may tap into to reinterpret existing knowledge and invent new ideas.

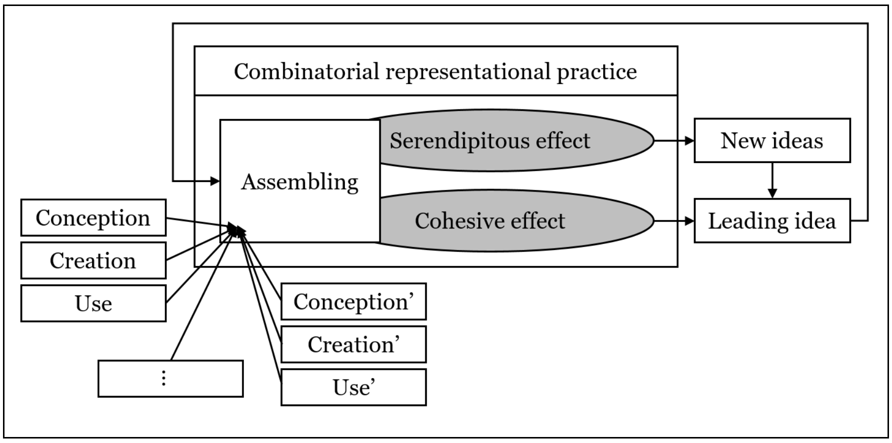


Figure 3.4 A process model of combinatorial representational practice

Building on the above discussion, I develop a process model of combinatorial representational practice (see Figure 3.4). Since such representational practice reveals itself as a flow of recombining representational practice components, I term it *combinatorial representational practice*.

Drawing on these insights, this study contributes to the digital innovation literature by explaining how digital technology enables combinatorial representational practice. Studies (e.g., Boland et al., 2007) are increasingly presenting new empirical evidence that the use of digital technology in representational practices contributes to the design of radical innovations; however, few explain how new representational practices differ from conventional ones. This study shows that digital technology makes a difference by unbinding the coupling between representational practice components, enabling designers to engage in a combinatorial representational practice. The idea of loose coupling and the combinatorial perspective offer future studies a new angle from which to examine and explain complex representational practices in the context of digital innovation.

This study also contributes to the design literature. It responds to Hobday et al.'s (2011, 2012) call for future studies to unveil the black box of design processes with insights on tools and processes used by designers. This study has identified three components of representational practice and examined how digital tools impact on representational practice. In the extant literature, most discussed representational practices are characterized by a tight coupling between representational practice components. Specifically, conception and creation are conducted by the same actor (Stacey et al., 1999), creation usually foresees how created representational objects will be used, and use abides by the original conception (Bogers and Horst, 2014). However, examination at the component level reveals that the tight coupling is being increasingly weakened as a result of using digital technology. This study highlights the necessity of examining representational practices at the component level in the digital age, especially examining new characteristics that result from dynamic interactions between heterogeneous components.

Another contribution of this study to the design literature is its link to a rising research trend - agile design. Agile design is argued to be an effective approach transforming ill-defined customer requirements into a product in a way that responds promptly to a constantly-changing design environment (Matthews et al., 2006, Kusiak and He, 1997). An agile design is often characterized by rapid iterations, frequent reflection and smaller teams (Wirfs-Brock, 2009). From this point of view, combinatorial representational practice is by nature equipped with the spirit of agile design, and thus fits well with the design of radical innovations characterized by a volatile design context. However, this study takes the agile attitude one step further. Agile design relies more on an outside-in process, which means it focuses more on swift improvements to temporary solutions through a continuous discovery of new problems in a changing context (Reich et al., 1999). In contrast, combinatorial representational practice relies on both outside-in (drawing on external resources to improve outcomes of previous design) and inside-out processes (even if there is no outside problem, a designer may actively appropriate an opportunistic discovery to improve previous designs and to conceive subsequent designs).

In addition, a similar concept to representational objects in the design literature is boundary objects (Star and Griesemer, 1989, Star, 2016). However, this study shows, as Ewenstein and Whyte (2009) also argue, that representational objects are multidimensional. Depending on how it is used, a representational object initially used as a boundary object may also serve as an epistemic object or a technical object in another context or agenda (Ewenstein and Whyte, 2009). This study further shows that, even in the same context and agenda, a representational object may also play different roles (e.g., the collection of online materials that served as a boundary object was simultaneously used for epistemic inquiries) and even all three roles at the same time (e.g., sketches in the co-sketching and 3D models in the co-modeling).

This study also has implications for practice in terms of how practitioners organize product design tasks in the digital era. Hatchuel (2001) proposes that design ability can be improved by "designing new learning-devices" and "looking for new forms of social interaction in design". This study shows that extra information introduced through combinatorial representational practice expands an initial idea, and that ensuring that information adheres to the initial idea is important for representational practices to clarify the idea effectively. Thus, the design of a new learning-device should consider how to incorporate further extra information and keep it related to the core idea. In addition, TopTech's dedicated sketch team offers a good model for practitioners to reconsider their organizational design in order to facilitate the communication of ideas between employees.

3.8 Conclusion

Drawing on an empirical study of a digital theatre design project in a Chinese pioneer in the entertainment business, this study has explored how designers assemble representational practices to generate radical digital innovations. The study reveals that the use of digital technology results in a loose coupling between representational practice components, enabling designers to conduct combinatorial representational practices. In a combinatorial representational practice, the assembly of components from diverse representational practices incorporates heterogeneous information and angles. This heterogeneity offers rich annotations to a leading idea, making it increasingly clear and also introducing valuable opportunities for the emergence of new ideas.

The combinatorial perspective presented in this study has significance for the study of design practice in the digital age. It allows representational practices to be examined at a more detailed level, which is critical to identify new changes in design practice and to achieve a more in-depth understanding of the underlying logic.

Focusing on the combinatorial perspective, this study sets out a new agenda for research. There is much more to be learned about digital technology-afforded representational practices. For example, this paper identifies an inside-out process in which a designer takes the initiative to appropriate opportunistic discoveries to generate new ideas. However, I have not examined this in detail as it is beyond the focus of this paper. Hence, further research might study how a designer decides whether an opportunistic discovery is relevant and capitalizes on it. Furthermore, this paper points out that, in a combinatorial representational practice, a representational object may simultaneously play multiple roles (as boundary objects, epistemic objects, and technical objects) without the change of the context or agenda. Hence, future research might study what unique characteristics enable this, and whether and how digital technology plays a part in these characteristics.

CHAPTER 4 PAPER 2 – STANDING OUT FROM THE CROWD

4.1 Introduction

Digital technology supports the ease and speed by which new innovation can be conducted (Nambisan et al., 2017). Innovation is democratized in that the cost of participating in novel product and service creation is reduced (Yoo et al., 2010b). While some of the major smartphone platforms are good examples of such democratization, where "a thousand flowers can bloom" (Boudreau, 2012), this ease is also becoming increasingly clear in traditional industries where products are digitized. For instance, as cars are becoming digitized, the ease by which new digital innovations are generated is prevalent (Svahn et al., 2017, Henfridsson and Yoo, 2014). However, the downside of this ease of innovation is the difficulty to innovate something that stands out as truly novel.

So, how can digital innovation be realized so it stands out from the crowd? Prior literature recognizes the novel characteristics of digital innovation (Nylén and Holmström, 2015), which keep challenging our conventional understanding of innovation (Nambisan et al., 2017) in terms of product architecture (Henfridsson et al., 2014), knowledge management (Lyytinen et al., 2016), organization design (Yoo et al., 2012), business strategy (Bharadwaj et al., 2013), entrepreneurship (Nambisan, 2016) and industry transformation (Benner and Tripsas, 2012, Boland et al., 2007). Indeed, while the literature recognizes the possibilities associated with digital innovation, little attention has been paid to the difficulty to generate truly new innovations. It is therefore relevant to learn more about the nature of digital innovation in terms of what generates the difference. *What is the process by which digital innovation generates novelty in its output?*

I selected a case study setting that offered ample opportunity to address this research problem. I studied TopTech's (pseudonym) innovation of a truly first digital theatre. The number of patents and the superior product performance associated with TopTech's digital innovation process astonished us. Despite having competitors in the entertainment business that also innovated digitally, TopTech managed to generate a novel digital theatre through a process where the newness of its business, contents, software, hardware, and form progressively was escalated and aggregated into a digital product distinctive from substitutes. In this regard, the case selection is extreme

(Gerring, 2007), offering a setting of paradigmatic interest for investigating the research problem. As Gerring (2007) notes, investigating an extreme case is particularly useful for theory building since the variables of interest display high values.

With this theory building ambition in mind (Gerring, 2007, Tsoukas, 1989), my conceptual starting-point was two-folded. First, I recognized that digital innovation takes place within and across architectural layers such as services, contents, networks, and devices (Tiwana et al., 2010, Tilson et al., 2010, Yoo et al., 2010b). This is a relevant aspect of the problem of ease-of-innovation since the layered nature of innovation increases the scope of possible connections between digital resources (Yoo et al., 2010b). Second, prior literature has recognized the importance of design in digital innovation (Boland et al., 2007, Yoo, 2013, Yoo et al., 2006). As Yoo et al. (2006, p.215) note, "the problem they [managers] face is a process problem", suggesting that innovation is an ongoing effort to creatively managing knowledge resources to move the limits of what is possible (cf., Nandhakumar et al., 2013, Henfridsson and Yoo, 2014, Boland and Collopy, 2004, Garud and Karnøe, 2003). In other words, it is essential to study the design process of digital innovation. In this regard, there are studies, therefore, suggesting that shifting the design locus from one layer to another may leverage the innovation level of final products (Henfridsson et al., 2014, Hylving and Schultze, 2013, Yoo, 2010). In this regard, design is key to understand digital innovation, and, in this paper, I cherish this insight by looking at movements of design locus in the layered architecture of digital innovation as a matter of design.

Synthesizing theories of design (e.g., Allert and Richter, 2009, Dorst, 2006, Dorst and Cross, 2001, Ulrich, 2011) and layered architecture of digital technology (Yoo et al., 2010b), I suggest viewing *novelty as reconstitution*. Based on this view and my analysis of data at TopTech, I develop a new process model of novelty generation in digital innovation. The process model specifically zooms in on what I refer to as reconstitutive cycles with which digital innovation is subsequently and gradually transformed in nature. I define *reconstitutive cycles* as the distinct moments of design evolution when (a) a digital innovation is rethought and (b), as a result, the design locus of the innovation activity changes. In turn, this changes the architectural context in which the digital innovation takes place. In my research at TopTech, I identified sixteen reconstitutive cycles that collectively resulted in novelty leaps in the design of the digital theatre, which eventually made it stand out.

This study contributes to the digital innovation literature by providing a process model that explains the process by which novelty in digital innovation is realized. Focusing on innovation novelty, the process model offers three implications for the emerging stream of digital innovation literature (cf., Nambisan et al., 2017). First, it specifies that the layered architecture of digital innovation makes innovation novelty emergent. Second, it explains that boundaries of innovation space become fluid because of the design of digital innovation keeps recreating innovation space. Third, it sheds light on the hybrid and opportunistic aspects of the design of digital innovation.

The remainder of the paper is structured as follows. I firstly review the literature on the ease of digital innovation. I then define novelty as reconstitution by synthesizing theories on the layered architecture of digital technology and design literature. This is followed by a description of the research method in terms of case selection, data collection and analysis. The subsequent section presents the empirical findings and synthesizes the findings into a process model of the generation of novelty in digital innovation. In the discussion and implications section, I discuss the implications of this study.

4.2 Conceptual Basis

4.2.1 The Ease of Digital Innovation

One of the most striking aspects of the digital innovation literature as it emerges in journal articles (Huang et al., 2017, Nandhakumar et al., 2013), special issue editorials (Barrett et al., 2015, Nambisan et al., 2017, Yoo et al., 2012), research commentaries (Fichman et al., 2014, Yoo et al., 2010b), and handbook book chapters (Lyytinen et al., 2017, Hukal and Henfridsson, 2017) the positive note with which it is written. In particular, this literature highlights how digital technology facilitates the innovation process by making it more democratic (involving more people) and lean (less resource-consuming) (see e.g., Kallinikos et al., 2013, Yoo et al., 2012, Yoo et al., 2010b, Ciriello and Richter, 2015). This ease has also been observed in traditional industries that typically would not be associated with digital technology and the innovation process associated with such technology. As an example, consider how the automobile industry is seeking to facilitate the generation of novel innovations at a faster pace by using digital technology (Henfridsson and Yoo, 2014, Svahn et al., 2017). In fact, this is not only valid for the use of digital platforms in cars (Lee and Berente, 2012, Henfridsson et al., 2014, Svahn et al., 2017) to stimulate generativity (Ghazawneh and Henfridsson, 2013, Eck and Uebernickel, 2016, Lyytinen et al., 2017), but also for digital innovations such as autonomous driving which is seen as a manifestation of how digital technology reshapes jobs and innovation practices (Brynjolfsson and McAfee, 2014).

A few observers recognize the downside of this ease of digital innovation. In particular, they raise the question what the ease by which “a thousand flowers can bloom” will make for the incentives to innovate (Boudreau, 2012) and how the abundance of substitutes in platform ecosystems (Basole, 2009) plays out. More importantly in the context of this paper, anecdotal evidence of the problem to stand out is increasingly visible in traditional industries too. The combination that software (a) empowers products (Yoo, 2010), (b) increasingly determines product characteristics (Svahn et al., 2017), and (c) facilitates innovation (Yoo et al., 2010b) raises questions about the nature of novelty in digital innovation. Essentially, if “the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology” (Nambisan et al., 2017, p.224) is easy, how can firms make sure that this creation indeed leads to novel innovations?

4.2.2 Novelty as Reconstitution of the Architectural Context of Design

So, what is novelty? Studies (Fichman et al., 2014, Wells et al., 2010) refer to *novelty* as distinctiveness perceived by experts or users. Nambisan et al. (2017, p.226) view digital innovation as a process of “dynamic problem-solution design pairing”. Adopting this view distinctiveness is created as the design process evolves to generate highly distinct problem-solution pairs. Such generation often comes with reshaping of the product architecture. In what follows, I synthesize theories of design (e.g., Allert and Richter, 2009, Dorst, 2006, Dorst and Cross, 2001, Ulrich, 2011) and layered architecture of digital technology (Yoo et al., 2010b) to build a conceptual foundation for understanding the creation of novelty in digital innovation.

Design in the context of innovation is not only to identify and solve existing problems but also to create new meanings (Verganti, 2013) and to impose designers’ vision (Nandhakumar et al., 2013, Clausen, 1993). In this sense, a design should be seen as a constitution including not only problems and solutions but also the proposition about why it matters to the past, present, and future situation that make it meaningful. Furthermore, since it is anchored in developing situations and designers’ subjective consciousness as such, a design should be seen as temporarily stable as it changes along with the change of the context where it is created and works.

Based on this understanding, I define *design* as a temporarily stable constitution of three interrelated constituent elements (design resource, design issue, and design proposal) identified, accumulated, changed, and associated in design practice. In addition to the temporarily stable nature of design, this definition appreciates the less predefined and more protean process and outcome of digital innovation (Nambisan, 2016, Nambisan et al., 2017, Yoo et al., 2010a). It also accommodates self-expressive design which becomes increasingly essential to innovation because of the fading division of engineering and artistic design (Boradkar, 2010) and the frequent reproduction of technical features for aesthetic purposes (Crilly, 2010).

The constituent elements jointly denote the flesh of a digital innovation. First, *design issue* denotes what a design is formed for. It includes but not limited to the idea of problem (Mayer, 1989, Simon, 1973) or gap (Ulrich, 2011) that imply a given starting-point of design. It also gives equal attention to designers' innate desire of self-expression in artistic design as a spontaneous start (cf., Kim, 2006). For example, music design may be initiated due to the impulse to create art (Trevarthen, 2012) without a given task. Second, *design proposal* is what a design offers. It can be "any results of intentional creation" (Ulrich, 2011, p.394). It includes, for example, a solution that responds to a given problem or an artwork inviting audiences to appreciate. It stresses the proposed nature of design creation (Allert and Richter, 2009). Third, the *design resource* includes beliefs, values and knowledge of designers that shape design decisions. For example, it concerns whether a problem matters (Gilhooly, 1989), and why a settled matching between problem and solution (Dorst, 2006, Dorst and Cross, 2001) is satisfactory. A design emerges from the interplay of these three constituent elements. When the interplay arrives at a temporary state, the interrelations between the elements inscribe rationales behind the historical process that informs why and how the triad arrive at the temporary state.

While a design of a digital innovation emerges, it often needs to be embedded into a larger context where a set of technological (e.g., software and hardware) and non-technological (e.g., business model and marketing materials) components enable or constrain its realization. The digital innovation and its related components jointly form the innovation architecture that emerges from the interplay between the design and the components. In this regard, I refer to such a context as the *architectural context* of design.

In digital innovation, the architectural context of design often takes a layered form (Yoo et al., 2010b). The layered form can be manifested as, for example, layered modular architecture (Yoo et al., 2010b), general layered architecture of cloud infrastructures (Pallis, 2010), and layered architecture of internet of things (Bandyopadhyay and Sen, 2011). These manifestations imply that design is by nature layered and a relative notion in digital innovation. In other words, a design can have its own layered architecture with components on different layers or as a component in the layered architecture of other design. As discussed below, digital innovation may emerge, in the former scenario, from designing all components that constitute a new layered architecture, or in the latter scenario, from designing a component that reconstitutes the layered architecture where it is located. For the ease of communication, I refer component designs of the same design as mutually *sibling designs*.

Adopting such a logical structure, digital innovation can be seen as an aggregation process in which constituent elements such as design resource, design issue, and design proposal form component designs, which, in turn, form digital innovations. This suggests that digital innovation comes with *movements of design locus*, which are location shifts of design focus from a design to somewhere in its architectural context. For example, to realize the point-and-click navigation technology innovation, Apple designed a computer mouse for moving the pointer to interact with the graphical user interface (GUI) of Macintosh. In order to enforce the use of the mouse, Apple removed the cursor arrow keys from the design of keyboards (Isaacson, 2011). Meanwhile, the mouse-based GUI control paved the way for the design of MacPaint, which was one the earliest graphics editors for drawing graphics digitally with a computer mouse. These examples show that innovations can be realized through movements of the design locus within the same (e.g., from mouse to keyboard on the hardware layer), or across (e.g., from the mouse on the hardware layer to the MacPaint on the software layer), product layers.

The consequences of moving the design locus are often the same: The emergence a new design (a) triggers the creation of sibling designs, or (b) requires the modification of sibling designs. Either consequence reconstitutes architectural context of the design. The difference between them is how the innovation in question is defined. In the former case, the eventual reconstitution of architectural context is the innovation in question. For example, in the MacPaint example, the mouse (point-and-click navigation technology) is the new design, and the software is the sibling design that worked together with the mouse to constitute the context of digital design innovation. In the latter case, the new design is the innovation in question. In the computer mouse example, the mouse was the new design and the innovation in question, and the keyboards were a sibling design that was required to be modified (Isaacson, 2011).

Since novelty implies a distinction between new and old, novelty can be studied by focusing on the emergence of a new design that results from reworking its old version. I refer to the moment that the new design emerges as a *reconstitutive cycle*, which appreciates the reconstitutive nature and the rework nature at the same time.

4.3 Research Approach

I conducted an in-depth case study (Gerring, 2007) of an innovative digital theatre project at TopTech, a pioneering technology company in the digital entertainment business in China. Originated in a media center of a Chinese public university in 1998, it started out as an animation outsourcing company. In recent years, it successfully managed to shift its business focus from animation outsourcing to the development of original products. Recognized as a “star high-tech company” by Chinese media, the turning point of its business transformation was the project involving its most iconic product, an innovative digital theatre. This product became a huge business success. In 2016, the project generated operating revenue of 31.66 million Chinese Yuan, a 107 percent increase year-on-year. With this product, the company had become a core supplier to first-tier theme parks in China. Reflective of its business success, the company received numerous awards from Chinese governmental authorities and domestic and overseas industry associations.

A B

Figure 4.1 The two versions of the digital theatre

The digital theatre offered a highly immersive 3D experience without the use of 3D glasses. It had two versions (see Figure 4.1) - a large version for outdoor use such as theme parks (see Figure 4.1-A) and a small version for indoor use such as shopping malls and trade fairs (see Figure 4.1-B). By September 2016, fifteen large theatres had been installed and used in theme parks across China. Several other large theatres were being produced and constructed. Several small theatres had been used in various domestic and foreign trade fairs and shopping malls.

4.3.1 Case Selection

In selecting an extreme case (Gerring, 2007), my research design was shaped by “theoretical relevance and purpose” (Orlikowski, 1993, p.312). In my wide search and strict screening of cases, I interviewed many top managers of candidate companies to make sure to identify a digital innovation setting where I could study the process of novelty generation. First, the digital theatre was novel. It was “considerably new to both the firm and to the market at the time of development” (Seidel, 2007, p.524). It offered unprecedented customer benefits and substantial cost reductions and designed business models novel to the theatre business (Slater et al., 2014). The digital theatre was characterized by radical technology changes (Norman and Verganti, 2014, Therrien et al., 2011) as the project had generated no less than thirty domestic and international patents. In other words, it showed early signs of business success (Dahlin and Behrens, 2005).

Second, the case involved significant use of digital technology. In fact, the digital theatre and its relevant services were not possible without digital technology. Such a heavy reliance on digital technology deeply affected the nature of its development. TopTech and its theatre project used a layered logic and showed indications that the design locus moved within and across the layers of the product. In this sense, this project was an extreme case (Gerring, 2007) for studying novelty generation in digital innovation by looking at movements of design locus in a layered architecture.

Third, I had significant data access. TopTech designed all components of the digital theatre. It also produced the content and critical software on themselves and was responsible for the transportation, installation, and maintenance of the digital theatres. This meant that the research site offered a rich setting for understanding the creation of novelty in digital innovation.

4.3.2 Data Collection and Analysis

I collected archival, observational, and interview data. First, archival data was important for gaining an initial understanding of the case context. Before I entered the research site, I, therefore, gathered documents such as business magazines, and online articles and videos as many as possible to attain a basic understanding of the company and its products and services. Even more importantly, following the access granted to technical documentation and patent specifications, I studied technical characteristics of the theatre in detail. I also collected textual, photographic, graphic, and video archival data to get detailed information not only about the process of the project but also about the company such as its business vision and corporate culture.

Second, I conducted two rounds of observation. The first was in June 2015 (48 hours), and the second was from December 2015 to February 2016 (252 hours). The location included TopTech's headquarters, customer companies' premises, and trade fairs. The observational data were recorded in forms of field notes and photos. The focus of observation was activities, events, and choices (Langley, 1999) that related to the ongoing development of new contents, functional upgrade, and the production, deployment, use, and maintenance of the theatres.

Lastly, I conducted 41 semi-structured formal interviews (between 20 and 90 minutes) with 43 interviewees in person during the main phase (from June 2015 to February 2016) of the data collection. Most interviews were conducted individually, but a few were group interviews, and some people were interviewed multiple times. For getting a cross-sectional view, interviewees covered a wide range of TopTech functional divisions and management levels. The interviews were voice recorded when there were no objections from the interviewees. Formal interviews were complemented with informal conversations with project members in day-to-day observations. Follow-up interviews were conducted either online or in person after the main phase of data collection, usually with the intention to clarify witnessed events and to confirm my interpretations of the data.

The data analysis started right after data collection began. I moved between data collection and analysis frequently, which was to improve the quality of data newly collected and my interpretations at the same time and to capture emerging themes. By recurrently revisiting the research site while analyzing data, I asked interviewees for comments on my interpretations. Their comments either confirmed the interpretation or revealed new understandings. As my understanding of the case became deepened, the focus of data collection was increasingly better directed and interview questions were continuously refined. I summarize my data analysis as a four-step process in Table 4.1.

First, I used an open coding procedure to discover critical component designs. The procedure included asking interviewees questions such as "which is indispensable for this digital theatre?" and "what are the selling points of this digital theatre?" I then established a timeline of the design process of the components through this coding procedure (see Figure 4.2). The horizontal arrows mean that the components were always under refinement when necessary. The dashed arrows mean that the emergence of a new design of a component was relevant to the design of another component.

Table 4.1 Data analysis process

Stages	Tasks	Outputs
1. Open coding of component designs	a. Identify critical component designs b. Create a timeline of the designs	Figure 4.3 Timeline of the design process of the digital theatre
2. Coding events of the emergence of designs	a. Excerpt events related to the emergence of the designs b. Identify why a design was needed c. Identify the significance of the outcomes	Table 4.2 Component designs
3. Coding design elements of new designs	a. Identify design resource, issue, and proposal of each new design b. Identify interrelations between the elements	Table 4.3 Design elements of new designs
4. Coding reconstitutive cycles	a. Group events based on whether the elements originated in the same product layer b. Identify forces that shaped reconstitutive cycles c. Analyse how a reconstitutive cycle impacted a design	Table 4.4 Types of reconstitutive cycles Table 4.5 Forces driving reconstitutive cycles Table 4.6 Evolutions and reconstitutive cycles

Second, I distinguished key events related to the generation, change, and fixation (Seidel, 2007) of the designs. An event was relevant if interviewees or project documents recognized them as a “version”, which usually indicated a significant change of a design. Due to its significance, a “version” left traces in both documents and project members’ memories; and, the data from the documents and interviews were comparatively consistent. I also analyzed why a design was needed and the significance of each design.

Third, I then identified new versions. I determined the existence of a new design as I recognized a change, or leap, of design that existed in the data as perceived versions. Analyzing series of new versions, it was able to understand how a product gradually evolves in terms of novelty. Hence, I zoomed in *reconstitutive cycles*, the moment of design evolution that lead to a new design. Using the theoretical lens developed above, I analyzed the design resource, issue, and proposal of each new design in terms of where they emerged, why they were adopted, and how they affected each other.

Fourth, I distinguished between two types of reconstitutive cycles, intra-layer and inter-layer. I then analyzed forces that drove the reconstitutive cycles and their significance to the design.

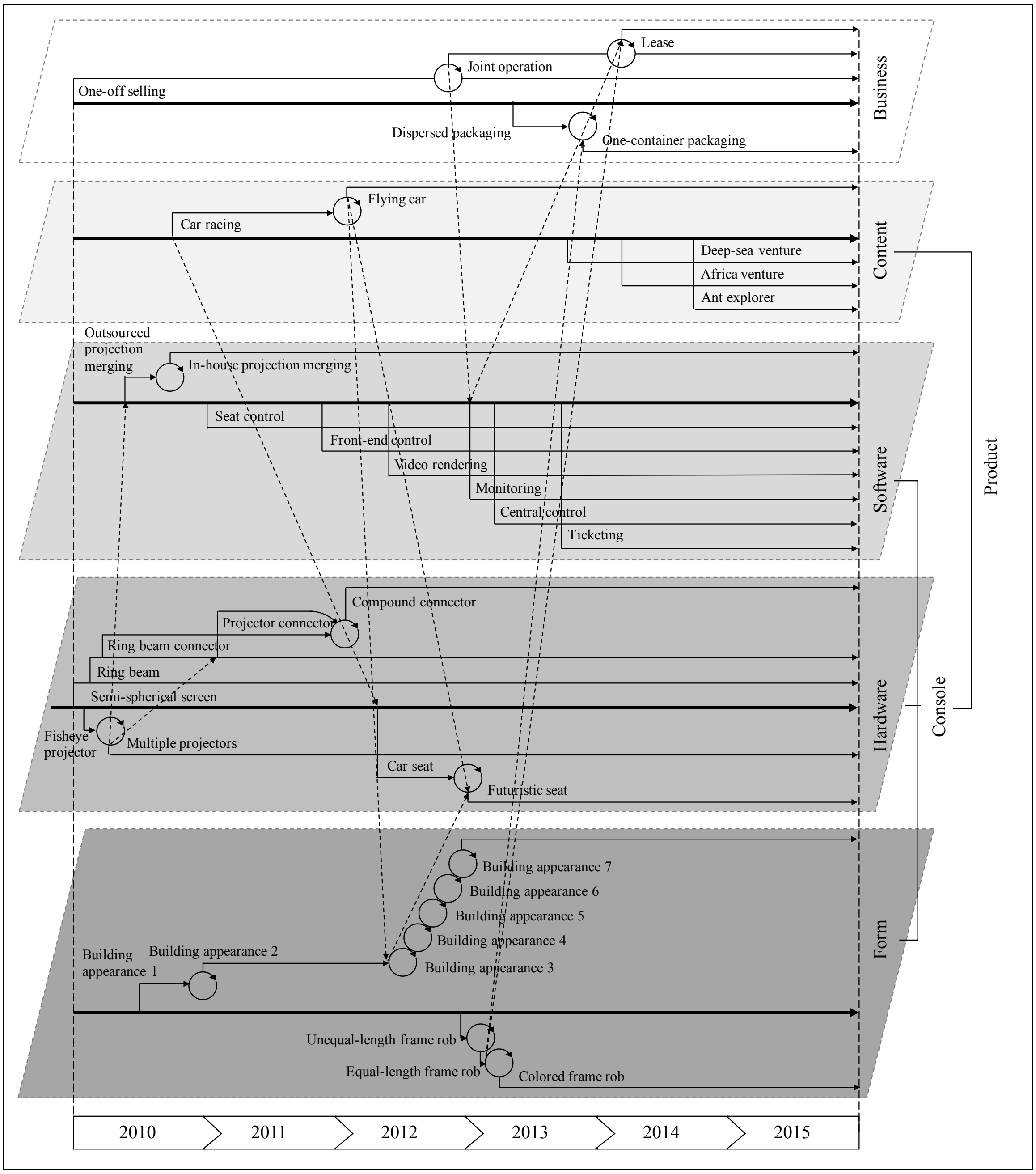


Figure 4.2 Timeline of the design process of the digital theatre

4.4 Case Description

The visit of TopTech's CEO to The Simpsons Ride at the Universal Studios Hollywood marked an important starting-point for the digital theatre project. At the same time, as the tourism industry increasingly attracted attention in China (e.g., the State Council of the People's Republic of China published *Opinions of the State Council on Accelerating the Development of Tourism Industry*), more and more theme parks were springing up across the country. Impressed by the experience of The Simpsons Ride and anticipating a theme park boom, he saw a business opportunity and believed that the company had to seize this trend by producing competitive theatre products for theme parks. On that very day, he spent most of the hotel night writing down his ideas in his notebook. Compared with The Simpsons Ride, he envisioned a theatre that would be more impressive across the line: audience experience, technical excellence, cheaper, and ease-of-use.

4.4.1 Product Layers of the Digital Theatre

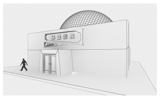
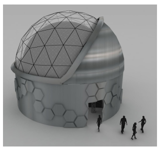
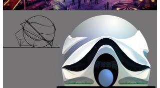
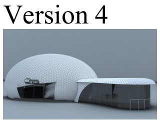
A digital theatre, whether large or small, consisted of two parts that the company called "content" and "structure". "Content" referred to digital animations, while "structure" run content and consisted of hardware, software, and form (building). Specifically, hardware included multiple projectors, a semi-spherical screen, motion seats, mechanical devices controlling the seats, computer, fans, lighting, and stereo equipment for rendering atmosphere, and the like. Software included media player system for playing animations, projection merging system for organizing projections of multiple projectors, diverse control systems for coordinating seats, fans, lighting, audio, and other equipment with animations to offer an integrated moviegoing experience, ticketing system, and monitoring system for real-time surveillance of daily operation and conditions of implemented digital theatres. Due to the relationship between "content" and "structure" was similar to that between "game software" and "game console" (c.f., Aoyama and Izushi, 2003), this paper renames "structure" as "console". This renaming is to avoid misunderstanding caused by the general use of "structure" in the extant literature which use the term to refer to an architectural arrangement of product components (e.g., Jiao et al., 2003). Above the content and console layers was the business layer, which included such as pricing, logistics, operation, and maintenance (see Figure 4.2).

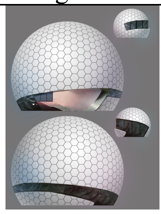
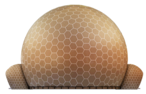
4.4.2 Design of the Product Theatre

This section introduces designs of product components that interviewees pointed out as critical and that had documented new versions. Table 4.2 summarizes information of them.

Table 4.2 Component designs

Components	Designs	Features
Projector	Version 1 (fisheye projector)	Using a fisheye projector to project an image to cover the whole screen. Ordinary visual effect.

Components	Designs	Features
	Version 2 (multiple projectors)	Using multiple ultrahigh-resolution projectors with each projector responsible for a part of the whole image, and all the projectors together covered the whole screen. Highly immersive visual effect.
Projection merging system	Version 1 (outsourced)	Outsourcing the system to a university research team. One-by-one merging. The merging time was two minutes.
	Version 2 (In-house)	Starting over with in-house engineers. One-click merging. The merging time was five seconds.
Ring beam and projector connector	Version 1 (dedicated)	Dedicated connectors for connecting the parts of a ring beam. And, dedicated holders for holding projector on the ring beam.
	Version 2 (compound)	Changed the ring beam connectors to make it capable of holding the projectors. Totally removed the dedicated projector holders.
Seat	Version 1 (motorsport)	The appearance of the seat resembled racing car seats. In line with a stereotypic idea of car seats.
	Version 2 (futuristic)	The theme changed, from realistic to futuristic. And, it had no armrests.
The first animation	Version 1 (car racing)	Ordinary auto racing in a racing track.
	Version 2 (flying car)	A science fiction animation in which futuristic flying cars chased and tussled with each other in a future city. A totally different theme and plot which was much more sophisticated than its antecedent. Its visual effect was also much more complex and dazzling.
Building	Version 1 	Imitating conventional movie theatres and planetarium. Reflected a stereotypical image of conventional movie theatres and planetarium.
	Version 2 	Glass and metal-based design to embody a "cool" appearance. More visually attractive but still looked very similar to ordinary movie theatres and planetarium.
	Version 3   	Imitating buildings in science fiction movies. A whole new theme. Hardly see its connection to previous version.
	Version 4 	Imitating spaceship in science fiction movies. Two buildings were connected by a corridor. The larger building was the main hall, while the smaller was the box office and waiting hall. Hardly see its connection to previous version.
	Version 5	Adopt the popular beehive pattern. Raised the concert hall to the first floor and used the ground floor as the waiting hall. The basic idea of this version was to highlight the beauty of succinctness. Although the box office is separated from the main building, this design still retained it.

Components	Designs	Features
		
	Version 6 	Moved the concert hall to the ground floor. Extremely similar to previous version. The only change was the movement of the concert hall from the first floor to the ground floor. The shaking problem was totally resolved.
	Version 7  	Further simplified the shape of the building to make it look more succinct. Removed the box office completely. Two entrances stretched out on both sides of the building Challenged the previous requirement that asked for a single globe for the main building and successfully defended its choice.
Building frame	Version 1 (unequal-length rod)	Rods of the building frame had unequal length. Their past project and other companies' approach also adopted this unequal-length rod design.
	Version 2 (equal-length rod)	Rods of the building frame used equal length. This needed complicated calculations and a painstaking trial-and-error design process. Probably because most competitor companies thought it was not worth spending time and money on such a design, there was no same design (to the its designer's knowledge). The building frame under installation in the construction site became visually pleasing, which often pleasantly surprised customer companies.
	Version 3 (coloured rod)	Marked different rods with different colours according to their locations. Enabled the assembler to identify rods with a single glance. It not only solved the construction problem but also largely improved the efficiency.
Business model	Version 1 (one-off selling)	One-off selling. The most common business model.
	Version 2 (joint operation)	Offering customer companies discount in exchange for a share of daily incomes generated by sold theatres. Largely reduced the price. Changed the logic from one-off selling to semi-selling (sharing the ownership). Developed a system for monitoring daily operations of a theatre.
	Version 3 (lease)	Leased theatres instead of one-off selling. This model moved away from the "transfer of ownership" logic. It also expended the potential customer base to the companies that only wanted to use the theatre once for a one-off event.
Transportation	Version 1 (sloppy)	Parts were scattered and organized dispersedly, since each part had a different shape and size. It was troublesome to check and move them.
	Version 2 (neat packaging)	Used a container to hold all parts together. Such a one-container design made the transportation more convenient and neatly beautiful.

The Design of Projector. Due to the semi-spherical shape of the cinema screen, a projected image by an ordinary projector would be distorted. Fisheye projectors were a common approach for the projection on a curved screen. Many planetariums that TopTech's designers visited or similar projects that they participated in were based on a fisheye-projector design that used one fisheye projector to project a whole image covering the whole semi-spherical screen. Hence, TopTech also adopted this design initially.

After the designers tried commercially available fisheye projectors, none of them could project images of a quality satisfying to them. For this reason, instead of using existing fisheye projectors, they collaborated with projector manufacturers to develop a new fisheye projector. Yet, no matter how hard they tried, they could not create a fisheye projector that met their strict requirement on image quality. Of course, the commercially available and newly developed fisheye projectors were not absolutely incompetent. However, as the CEO assistant explained, because of their animation business background, most employees saw themselves as an artist and wanted all their creations to be perfect. Besides, the company expected this digital theatre to become its iconic product, which also required the product to be excellent in all respects.

As a result, they gave up the fisheye-projector design and shifted their focus to a multi-projector approach. The new design used multiple ultrahigh-resolution projectors. The projectors were attached to a giant metal hoop, which was on the edge of the semi-spherical screen supporting the screen. Each projector was responsible for projecting on a part of the screen. All the projectors together presented the whole image.

The Design of Projection Merging System. Because of the use of multiple projectors, a specialized software system was necessary to coordinate their respective projections. At the beginning, TopTech employed a university research team to develop the system. Since the design of the projector holder was not determined at the time, the team figured out a way to coordinate the projections without a sophisticated algorithm in order to realize flexibility for later change of the projector holder design. As a project manager in the New Business Development Department said, this system revealed TopTech's in-house engineers that the seemingly complicated projection merging task could be resolved with a relatively simple programming logic that even themselves could easily create. This outsourced development laid the foundation for the later in-house development of a new version of the system.

After the projector holder design was decided, TopTech tested the initial projection merging system. Although the system functioned very well, its setup process was tedious. The projectors had to be configured one by one. This tiresome time-consuming process contradicted ease of use which was expected to be a critical selling point of the product. Besides, as the company gradually accumulated experiences through their study on the industry status, they realized that this system should be a core technology of the product and should be protected. Because of these business concerns and because in-house engineers realized that they could create the system on themselves, TopTech decided to create a new version with its own in-house engineers. With this new system, the calibration of separately projected images became easier and merging projections needed merely one click of the mouse. This one-click design also enabled the engineers to further improve the efficiency of the merging algorithm that significantly reduced computation time from two minutes to thirty seconds and eventually to five seconds.

The Design of Compound Ring Beam and Projector Connector. The semi-spherical screen was fixed on a giant metal hoop, called ring beam. A ring beam was divided into several equal arc parts. Initially, a dedicated ring beam connector was designed for connecting the parts. Since the projectors were designed to be attached to the ring beam, a dedicated projector holder was also designed for this purpose. However, as the deputy manager of the New Business Development Department recalled, some designers later found it doltish to use two kinds of dedicated connectors as they could change the ring beam connector to hold the projectors. Besides, they found that the installation and calibration were inconvenient and error-prone when there were too many connectors.

The new design, hence, was a compound ring beam and projector connector that fixed ring beam parts and held projectors at the same time. This design made the dedicated projector holder redundant and eventually removed it from the final design of the theatre. Using this compound connector eased the installation and calibration and reduced mistakes such as positional and angular deviation caused by using dedicated projector holders.

The Design of Seat. The initial seat design was inspired by the initial version of the first animation themed “Car Racing”. Its appearance resembled ordinary motorsport seats with two armrests.

The second version had two significant changes: its futuristic theme and the removal of the armrests. As the CEO introduced, their animation business background made them believe that content should be the most important factor in an entertainment business; hence, they granted a high priority to animations over other parts of the theatre in its design decision making. As the science fiction-themed new version of the first animation took form gradually, the seat designer was inspired by it and designed a futuristic seat appearance. This design fitted well with the first animation; however, it did not match themes of following animations such as Deep Sea Adventure, Africa Adventure, and The Ant Explorer. As the manager of the Entertainment Experience Design Center explained, this design was retained because the science-fiction theme of the first animation became a leading concept of the whole theatre that even affected the building design. In addition, TopTech wanted to enhance the “high-tech product” image of the theatre and believed a futuristic appearance of hardware could convey such an impression.

Another change in the new design was the removal of armrests, which replaced the armrests with metal rings (looked like handles on a pommel horse). As the chief designer of the Entertainment Experience Design Center explained, this change was to increase audience capacity. The predefined business goal (daily income) required more audience capacity. However, the building design was required to use as small building area as possible, which constrained available indoor space. Hence, the only reasonable solution was to reduce seats’ width to improve space utilization.

The Design of the First Animation. The initial version of the first animation was “Car Racing”, in which a fierce racing competition of ordinary cars took place in an ordinary racing track. TopTech wanted this animation to be able to impress audiences with an “exciting” experience. Through a wide search online and offline, they found that car racing was usually associated with “exciting” experiences. Resorting their experience in the animation business, TopTech developed the animation.

Meanwhile, the development of seat control system was finished. The system was to synchronize the movement of seats with the plot of the animation. TopTech used the “Car Racing” animation to test whether the system could work properly. The experience of the test revealed two things to the designers. First, they found that the acceleration of cars in the animation was not abiding by the correct acceleration rate. When the animation was watched separately, designers did not feel anything wrong. However, watching it with the seat control system designed with the correct acceleration rate, designers had a sense of incongruity and felt that the movement of cars in the animation was unnatural. Second, the test offered the designers a chance to watch the animation as an audience. After the test revealed the acceleration issue, some designers also felt that the plot of the animation was not sufficiently exciting and might not impress audiences as they expected. As a designer of the Contents Development Department said, once they started to see a problem in it, the more they watch it the more they dislike it.

Hence, they continued to search for a more exciting theme to refine the animation. The search led to an idea to equip cars with a flying capability, which was a science fiction animation, “Flying Car”. In this new version, futuristic flying cars chased and tussled with each other in a future Chinese city. In the creation of this new version, they consulted software and hardware engineers with sufficient physics knowledge to make the animation look more natural.

The Design of Building. The initial design of the building looked very like an ordinary planetarium. It also reflected a stereotypical image of conventional movie theatres. In addition, this design was required to save the building area. However, when the designer brought it to the CEO, he thought that the design was mediocre and not visually appealing. What he wanted was a “cool” building. The overarching requirement for the product was to impress audiences, the building was also expected to be able to visually impactful.

The second version focused on how to make the building more visually attractive. Collecting and analyzing pictures of world famous buildings, the designer concluded that buildings usually recognized as “cool” were often characterized by heavy use of glass and metal materials. Using glass and metal as main materials, the new design inherited characteristics of the previous version such as the appearance that highlighted the semi-spherical shape of the screen and the concern of saving the building area. However, the CEO still thought it was not visually appealing enough. Besides, glass and metal materials were usually expensive which contradicted TopTech’s past business experience that few customer companies had abundant financial resources. At this time, since the “Flying Car” animation gradually took shape, its science fiction theme led to an idea that “futuristic” should be a keynote of the whole product, and thus should also be the key concept of building design.

Looking for inspiration in a great volume of science fiction movies and keeping characteristics such as globe-shaped, space-efficient, and cool, the third version embodied the “futuristic” concept and were more visually appealing. However, the complicated structure was estimated to require more construction time. Meanwhile, as “simplicity is the ultimate sophistication” increasingly became a buzzword in the field of consumer electronics design, the CEO eventually gave a more concrete requirement that "visually appealing" should mean the beauty of succinctness.

The fourth version had two buildings connected by a corridor. The larger building was the main hall, while the smaller was for box office and waiting hall. This design met the requirements asked so far such as globe-shaped, space-efficient, cool, futuristic, and the beauty of succinctness. The estimated construction time was also acceptable. However, the CEO thought the smaller building and the corridor compensated the beauty of the main building. Besides, whether a box office was functionally necessary was also in question.

As the search of inspiration went on, the designer found that the shape and pattern of beehives were becoming popular in the field of architectural design. The perfect-sphere shape of this fifth version offered more indoor space while saving more building area. This design raised the concert hall to the first floor and used the ground floor as the waiting hall. As the necessity of the box office was still in question, the designer also made a design for it but separated it from the main building. However, when the model was tested with building simulation software, it was found that the movement of devices under the seats in the concert hall upstairs caused a significant shake of the whole building. The shake might result in the vibration of projectors, which would negatively affect the image quality.

The sixth version moved the concert hall to the ground floor in order to reduce the shake. It was about at this stage that the company started to design the interior of the building. The interior design led them to concern the number and arrangement of the seats. Needless to say, the more seats there were, the more audiences could be accommodated and thus the more money a theatre could earn. This business concern presented a new requirement for the building design, and they found the invaginated door and waiting hall of the building occupied a large indoor space that could be used for more seats.

Taking all the esthetic, functional and business requirements into account, the seventh version moved the door and the waiting hall of previous versions outside the building. It further simplified the appearance of the building to make it look more succinct. It also removed the box office completely. Inheriting recognized characteristics of its antecedent versions, this design was a perfect sphere with the beehive pattern on its surface. The only characteristic that offended a requirement presented in previous stages was two entrances that stretched out on both sides of the building. This, as the designer of the Entertainment Experience Design Center explained, was mostly a compromise to the business requirement.

The Design of Building Frame. TopTech's and other peer companies' past projects often used rods with different lengths for the frame of a globe-shaped building. The unequal-length design functioned well hitherto. From a functionality point of view, there was no need to change this design. This was also more convenient for designers to decide the length of rods at the bottom of the frame. Hence, the initial building frame design followed this approach.

However, again, TopTech's enrooted artistic temperament and pursuit for a perfect iconic product affected the design. TopTech wanted the frame look exquisite during its assembly at the construction site, even though audiences would never see the frame after the construction was finished. Since the designer preferred symmetry, he thought it would make the frame and its assembly process look elegant if all rods had the same length. Hence, the designer conducted a painstaking trial-and-error process and eventually created a new design using equal-length rods.

However, after they manufactured the building frame, TopTech found an unexpected problem. Since all rods had the same length, it was difficult for assemblers to know where a rod should be put. The location of a rod mattered because there were different grooves on different rods and different connectors for connecting them and holding interior and exterior walls to them. Although assemblers could know where a rod should be put by looking at the form and shape of the grooves and connectors, it relied on their familiarity with the rods and proficiency of assembly, which was time-consuming and error-prone. This issue contradicted the business requirement that expected ease of use to be a selling point of the product. Reflecting on such a feedback from the construction site, the designer decided to refine the design.

The most straightforward way was to number the rods. However, TopTech expected the installation process to be as smooth as possible. They thought it was still troublesome to check and pair numbers on so many rods and wanted to make the identification of rods easier and intuitive. Hence, instead of numbering the rods, the designer marked rods with different colors according to their different locations, which enabled assemblers to identify rods with a single glance.

The Design of Business Model. TopTech had some experiences of theatre building projects, which sold a whole theatre to customer companies. However, as they experienced, the theatres were too expensive that few companies had abundant financial resources to buy a whole theatre. Due to such experiences, TopTech estimated that there would not be many companies capable of purchasing this digital theatre at its full price, even though they had managed to largely reduce the production cost and hence the price. They faced the challenge to lower the price further in other ways.

For this reason, TopTech designed a new business model that gave customer companies discount in exchange for a share of daily incomes generated by sold theatres. In order to share the incomes, it was necessary to know how many audiences visited the theatres. For this purpose, they developed a system for monitoring daily operations of a theatre. For their ingrained passion for perfection, the designers pursued a perfect monitoring system. They embedded as many functions regarding operating conditions of a theatre as possible into the system. As a result, it could collect data of not only the number of audiences but also the condition of equipment.

As the project progressed, TopTech gradually realized that the building was assemblable and enhanced this idea in subsequent design. This meant the theatre could be taken apart and reassembled for next use. In combination with the monitoring system, it was able to know whether a theatre was in a good condition and maintain it in time. Since they could know the condition of critical components of a theatre in use, they could know whether it was reusable. TopTech saw a chance in such a reusability and designed a new business model that leased theatres instead of one-off selling. This new business model also expanded their customer base from rich companies to those that had limited resources or only wanted to use a theatre for a one-off event.

The Design of Transportation. At the beginning when the length of building frame rods was unequal, transportation was inconvenient. Building parts were scattered and organized dispersedly since each part had a different shape and size. It was troublesome to check and move them. However, the equal-length design of building frame rods revealed an opportunity to create a one-container design that used a container to hold all the parts. When the length was unequal, to design such a packaging was difficult because the container must fit with the largest part and left too much unused space in which smaller parts might move and collide with each other. In contrast, the equal length enabled the parts to be put compactly. Such a packaging design made the transportation more convenient. Using the CEO assistant’s words, this design “even made the transportation process so beautiful”. This packaging often impressed buyers when they saw that only one container was transported to the construction site and everything in it was neatly organized.

4.5 Findings

The empirical data reveals that the novelty of the theatre was realized through aggregating consecutive emergence of new component designs. Studying critical product components reported by interviewees and recorded in project documents, I identified and zoomed in on sixteen reconstitutive cycles to investigate the process of novelty generation.

4.5.1 Types of Reconstitutive Cycles: Intra-Layer and Inter-Layer

I analyzed the elements of each new component design resulted from sixteen reconstitutive cycles (see Table 4.3). In the table, “DR” “DI” and “DP” are short for “design resource” “design issue” and “design proposal” respectively.

Table 4.3 Triad elements of new designs resulted from re-constitutive cycles

New component designs		Triad elements of new designs		Layers
Projector design	Design 2 (multiple projectors)	DR	This product should be iconic and hence top-quality	Business
		DI	Better image quality	Hardware
		DP	Multiple ultrahigh-resolution projectors	Hardware
Projection merging system design	Design 2 (in-house)	DR	The system should be a core technology and protected	Business
			Ease of installation	Business
		DI	The separated projection of multiple projectors	Hardware
		DP	In-house developed system	Software
Ring beam and projector connector design	Version 2 (compound)	DR	Ease of installation	Business
		DI	Inconvenient and error-prone installation	Business
		DP	Combining ring beam and projector connector	Building
Seat design	Version 2 (futuristic)	DR	“Flying Car” animation	Content
			The belief that content was most critical factor	Business
			Available space	Building
			Audience capacity	Business
		DI	The appearance of the seat	Hardware
		DP	Futuristic appearance	Hardware
			Removal of armrests	Hardware
The first animation design	Version 2 (flying car)	DR	This product should impress visitors greatly	Business
			Knowledge of physical laws	Software
		DI	More exciting movie plot	Content
			Sense of reality	Content
		DP	Combination of aircraft and racing	Content
			Natural movements	Content
Building design	Version 2 (glass and metal)	DR	Popular materials in the architectural field	Building
		DI	More visually appealing building appearance	Building
		DP	See the second version of building design in Table 4.2	Building
	Version 3 (science fiction)	DR	The science-fiction theme of the first animation	Content
			The belief that content was most critical to the success of an entertainment business	Business
		DI	More visually appealing building appearance	Building
		DP	Futuristic building appearance	Building
	Version 4 (simplicity)	DR	A buzzword in the consumer electronics industry	Business
		DI	Visually appealing building appearance	Building

New component designs		Triad elements of new designs		Layers
	Version 5 (ensemble beauty)	DP	Succinct building appearance	Building
		DR	Increasing popularity of beehive pattern in the field of architectural design	Building
		DI	More visually appealing building appearance	Building
		DP	Highlighted the concert hall and emphasize the ensemble beauty of the whole building	Building
	Version 6 (vibration reduction)	DR	Knowledge from building simulation system	Building
		DI	Reducing the shake of building	Building
		DP	Moved the concert hall to the ground floor	Building
	Design 7 (audience capacity)	DR	The expected daily number of audiences	Business
		DI	Improve indoor space utilization	Building
		DP	Removed waiting hall and stretched-out entrances	Building
Building frame design	Version 2 (equal-length rod)	DR	The assembly process should look good	Business
		DI	An elegant look of the building frame	Building
		DP	Rods with the same length	Building
	Version 3 (coloured rod)	DR	The installation should be fluent and intuitive	Business
		DI	The difficulty to distinguish rods	Building
		DP	Different colours for rods in different locations	Building
Business model design	Version 2 (joint operation)	DR	The experience-based estimation that few companies had enough financial resources to buy a whole theatre	Business
		DI	Reducing purchase price	Business
		DP	Discount in exchange for daily incomes from sold theatres	Business
	Version 3 (lease)	DR	Monitoring software	Software
			Assemblable building and equipment	Building
		DI	Reduce purchase price	Business
		DP	Lease instead of purchase	Business
Transportation design	Version 2 (neat packaging)	DR	Equal-length rods	Building
		DI	Messy transportation	Business
		DP	Containing all parts in one container	Business

Based on the source layer of each element, I distinguished two types of reconstitutive cycles: *inter-layer* and *intra-layer*. A reconstitutive cycle is intra-layer when all the elements of a new design are from the same layer; otherwise, it is inter-layer. According to this definition, twelve of the sixteen reconstitutive cycles are inter-layer and four are intra-layer (see Table 4.4). In the following analysis, "$\xrightarrow{=}$" indicates both of its ends are on the same layer, "$\xrightarrow{\parallel}$" indicates they are from different layers, and ":" indicates the interrelation between them.

Table 4.4 Types of re-constitutive cycles

New designs	Types	Counts
Building design version 2 (glass and metal) Building design version 5 (ensemble beauty) Building design version 6 (vibration reduction) Business model version design 2 (joint operation)	Intra-layer	4
Projector design version 2 (multiple projectors) Projection merging system design version 2 (in-house) Ring beam and projector connector design version 2 (compound) Seat design version 2 (futuristic) The first animation design version 2 (flying car)	Inter-layer	12

Building design version 3 (science fiction) Building design version 4 (simplicity) Building design version 7 (audience capacity) Building frame design version 2 (equal-length rods) Building frame design version 3 (coloured rods) Business model design version 3 (lease) Transportation design version 2 (neat packaging)	
Total	16

Specifically, intra-layer reconstitutive cycles generate new designs by discovering new design resources, identifying new design issues, and conceiving new design proposals on the same layer of old designs that are to be replaced. For example, building design 6 was generated to deal with the vibration problem discovered in building simulations (building layer resource $\overset{-}{\underset{-}{\rightarrow}}$ building layer issue: formulate) by moving the concert hall to the ground floor (building layer proposal $\overset{-}{\underset{-}{\rightarrow}}$ layer building issue: solve) to avoid the building shake (building layer resource $\overset{-}{\underset{-}{\rightarrow}}$ building layer proposal: evaluate). In business model design 2, designers estimated that few companies could purchase a whole theatre based on their previous experience and sought to reduce the price (business layer resource $\overset{-}{\underset{-}{\rightarrow}}$ business layer issue: formulate) by giving discount in exchange of daily incomes from sold theatres (business layer proposal $\overset{-}{\underset{-}{\rightarrow}}$ business layer issue: solve, business layer resource $\overset{-}{\underset{-}{\rightarrow}}$ business layer proposal: justify). This analysis on inter-layer reconstitutive cycles shows that new designs of intra-layer reconstitutive cycles often improve antecedent designs with better design proposals achieved with enriched design resources to hand leftover design issues.

In contrast, when inter-layer reconstitutive cycles generate new designs, design resources can be design proposals from other layers, design proposals can be justified by design resources from other layers, design issues can be clarified by design resources from other layers, and the like. For example, in ring beam and projector connector design 2, a pursuit for ease of use highlighted the troublesome installation (business layer resource $\overset{-}{\underset{-}{\rightarrow}}$ business layer issue: identify) which led to the new design that reduced the number of different types of connectors (building layer proposal $+\!\!+\!\!\rightarrow$ business layer issue: solve) which simplified the installation process (business layer resource $\overset{-}{\underset{-}{\rightarrow}}$ business layer proposal: evaluation). In building frame design 2, the expectation of an elegant assembly process prompted the designer to improve the look of the building frame (business layer resource $+\!\!+\!\!\rightarrow$ building layer issue: formulate), which led to the use of robs with equal length (building layer issue $\overset{-}{\underset{-}{\rightarrow}}$ building layer proposal: embody) that eventually met the designer’s taste (business layer resource ⇻ building layer proposal: evaluate). This analysis on inter-layer reconstitutive cycles shows that when taking elements from heterogeneous layers into account, designers face the challenge to unite the heterogeneity to make them a harmonized and stable design. Uniting heterogeneous elements reveals valuable design opportunities (e.g., by prompting them to identify or formulate new design issues) to reconsider their current designs, which leads to new designs.

4.5.2 Forces Shaping Reconstitutive Cycles: Compulsory and Autonomous

I identified two forces that shape reconstitutive cycles (see Table 4.5).

Table 4.5 Forces driving re-constitutive cycles

New designs	Forces	
	Compulsory	Autonomous
Projector design version 2 (multiple projectors)	Projecting on the semi-spherical screen.	Although the fisheye projector was seen as an acceptable approach to peer companies and TopTech’s previous projects, TopTech’s designers expected image quality to be as good as possible.
Projection merging system design version 2 (in-house)	Coordinating multiple projectors. Protecting the core technology.	Although the outsourced system functioned well, TopTech’s engineers expected the setting process to be as easy as possible. In-house engineers realized that they could develop the system on them own.
Ring beam and projector connector design version 2 (compound)	Connecting ring beam parts. Fixing projectors. Resolving the actual error-prone installation.	Although the two separate connectors could fulfil the basic requirement, TopTech’s designers expected the installation to be as convenient as possible. The designers felt it weird to have two separate connectors.
Seat design version 2 (futuristic)	Seats were indispensable components. The limited available indoor space constrained the grandstand frame. The targeted audience capacity required the seat to reach a certain number.	The designer believed the futuristic appearance could create a “high-tech” image of the product. A belief rooted in the company that content should be at the heart of an entertainment business.
The first animation design version 2 (flying car)	The acceleration of cars in the animation was not abiding by the correct acceleration rate.	Although they could just correct the acceleration rate, the critical stance in testing pushed some designers one step further to think that the plot was also not sufficiently exciting. The designers wanted the animation to be as exciting as possible.
Building design version 2 (glass and metal)	The building was an indispensable component.	The CEO thought the previous was not visual impressive enough.
Building design version 3 (science	The building was an indispensable component.	The CEO preferred a “futuristic” theme. A belief rooted in the company that content

New designs	Forces	
	Compulsory	Autonomous
fiction)	Previous material was estimated to be too expensive.	should be at the heart of an entertainment business.
Building design version 4 (simplicity)	The building was an indispensable component. The construction of the previous was estimated to take too long time.	“Simplicity is the ultimate sophistication” became a popular design philosophy. The CEO thought that “visually appealing” should mean the beauty of succinctness.
Building design version 5 (ensemble beauty)	The building was an indispensable component. The necessity of box office was still in question.	The CEO felt the box office in previous design and the corridor compensate the overall beauty of the main hall.
Building design version 6 (vibration reduction)	The building was an indispensable component. Building simulation revealed that the vibration of motion seats might cause the shake of the building.	N/A, since this version was mainly triggered by an unacceptable engineering problem.
Building design version 7 (audience capacity)	The building was an indispensable component. The ideal number of audiences. Available indoor space.	Without a rational reasoning, the designers decided it was a proper timing to make an acceptable compromise to the business requirement.
Building frame design version 2 (equal-length rods)	Supporting the whole building, the exterior and interior wall.	The designer wanted all aspects of the product perfect including the construction process. Although audiences could not see the building frame after the building was established, the designer wanted the building frame look exquisite during its assembly in the construction site. Designer also preferred symmetry.
Building frame design version 3 (coloured rods)	Supporting the whole building, the exterior and interior wall. It was difficult for assemblers to know where a rod should be put.	The most straightforward way was to number the rods. However, the designer thought it was still troublesome to check and pair numbers on so many rods. They wanted to make the identification of rods easier and intuitive.
Business model design version 2 (joint operation)	Generating business income. Few companies had enough financial resources to purchase a whole theatre.	The designers were always thinking how to further reduce the price. Even though they had managed to largely reduce the production cost, they decide to reduce the price by delaying the collection of income.
Business model design version 3 (lease)	Generating business income. Few companies had enough financial resources to purchase a whole theatre.	The designers were always thinking how to further reduce the price. Seeing the versatile monitoring system and the assemblable building, they realized that the product could be reusable and decide to take advantage of this opportunity by offering a new business model.
Transportation design version 2 (neat packaging)	Transporting the product to the use site.	The equal-length design of building frame rods, which enabled the parts to be put compactly in a comparatively small space. The transportation process should also be “beautiful”.

Compulsory forces mean a new design is functionally necessary. Without the new design, the overall product cannot function. There are two situations that compulsory forces come into play and lead to reconstitutive cycles. In the first situation, an antecedent design revealed a new requirement that must be dealt with by the new design. For example, building design version 5 presented the building shaking problem, which must be fixed by building design version 6. The market reality from previous business experience that few companies had enough financial resources also posed an unavoidable requirement for the design of the joint-operation business model. In the second situation, a sibling design revealed a new requirement that must be dealt with by the new design. For example, the seat control system that used the correct acceleration rate required to a re-design of the initial version of the first animation. Similarly, the projection merging system was indispensable due to the use of multiple projectors.

Autonomous forces mean a new design is not functionally indispensable. They are often due to designers' personal preferences, values, and beliefs. For example, the CEO asked for a "cool" building appearance, which he did not have clear criteria that could be used for evaluating to what extent an appearance was "cool". Whether a building design met his requirement depended purely on his subjective judgment at the moment he saw it. Similarly, the futuristic seat design was also due to the designer's subjective judgment. Although it seems a response to the science fiction theme of the first animation, it was not rational as it did not meet themes of most subsequent animations. A more rational design should be able to meet a wide range of animations. Hence, it was more of a choice out of personal preference.

In this sense, autonomous forces are often exerted by requirements that are a specific expression of design attitude that is specialized and localized for current design work. A *design attitude* refers to designers' expectation about the most ideal status of the final design outcome, which orients their design activities. The design attitude appeared frequently in the empirical data is project members' passion for perfection born from their artistic temperament. This design attitude when it was implemented by system designers, was to embed as many related functions to the monitoring system as possible; by frame designers, was to make the assembly process as beautiful as possible; and, by animation designers, was to make the animation as exciting as possible.

An autonomous force may become a compulsory force. For example, the science fiction theme of the first animation initially emerged as a personal pursuit of the animation designers for an "exciting" moviegoing experience later became a key concept for building design. However, different from compulsory forces exerted by functional and business needs that are often inheritable (see the middle column in Table 4.5), compulsory forces from autonomous forces may be abandoned. For example, the CEO required building design version 5 to keep the main building as a single globe to realize its ensemble beauty, which became compulsory for following building design. This requirement was abandoned in the final building design that had two entrances stretched out the building.

4.5.3 Design Evolutions and Reconstitutive Cycles: Intensive and Extensive

Inter-layer or intra-layer reconstitutive cycles result in design evolutions that exceed antecedent designs, which in turn reconstitute their architectural context and generate novelty. Evolutions resulted from the two types of reconstitutive cycles are different in terms of whether new designs change the fundamental design logic of their antecedents. I term evolutions in which new designs retain antecedent designs' logic as *extensive evolutions*, while those that change the design logic as *intensive evolutions*. This term use is inspired by Delanda's (2016, p.110) work that use "extensive boundaries" to refer to natural and artificial frontiers that denote zones in which biological organisms and social agents live, and "intensive boundaries" to refer to "critical points at which quantitative changes become qualitative". In other words, extensive evolutions are making a design "better", while intensive evolutions are making a "different" design.

On the one hand, extensive evolutions are closer to the co-evolution of problems and solutions (Dorst and Cross, 2001) around a given core problem on the current problem-solution plane. For example, building design version 2 extended its antecedent with new materials; however, as their pictures in Table 4.2 show, they look very similar and both reflect a stereotypical image of conventional planetariums and movie theatres. Similarly, both building design version 5 and 6 followed their antecedents' design logics and improved them by altering unsatisfying features and adding new features.

On the other hand, intensive evolutions challenge antecedent designs fundamentally, which change the given core problem and shift to other problem-solution planes, or even transform the nature of design tasks, for example, from the engineering to the artistic. The design of the compound ring beam and projector connector is a typical instance. It reconsidered and denied the necessity of a dedicated projector connector. Similarly, the multiple projector design shifted the focus from how to improve the quality of a single fisheye projector to how to coordinate multiple ultrahigh-resolution projectors. Although the final building design looked similar to its antecedent, it contradicted the specification established in previous designs that required to use a single globe.

Data show that a tendency that intra-layer reconstitutive cycles are more likely to result in extensive evolutions, while inter-layer reconstitutive cycles are more likely to result in intensive evolutions (see Table 4.6).

Table 4.6 Evolutions and re-constitutive cycles

Re-constitutive cycles	Evolutions	
	Intensive	Extensive
Intra-layer	Business model design version 2 (joint operation) Switched one-off logic to partnership logic	Building design version 2 (glass and metal) Used more polished building materials Building design version 5 (ensemble beauty) Separated the main building and the small hall Building design version 6 (vibration reduction) Solved the building shake installation issue in the previous design
Inter-layer	Projector design version 2 (multiple projectors) Denied the conventional fisheye projector approach Ring beam and projector connector design version 2 (compound) Denied the necessity of a dedicated projector holder Seat design version 2 (futuristic) Changed genre from realistic to futuristic The first animation design version 2 (flying car) Changed genre from realistic to futuristic Building design version 3 (science fiction) Changed genre from realistic to futuristic Building design version 4 (simplicity) There was no obvious clue showing its connection to the previous design Building design version 7 (audience capacity) Denied the previous requirement that using a single globe for the main building Building frame design version 2 (equal-length rods) Denied the more straightforward unequal rod approach Building frame design version 3 (coloured rods) Used an artistic means to deal with an engineering issue and raised the assembly process to the “beautiful” level Business model design version 3 (lease) Switched selling thinking to renting thinking Transportation design version 2 (neat packaging) Raised the transportation process to the	Projection merging system design version 2 (in-house) Kept the algorithm confidential Made the calculation faster and the configuration more convenient

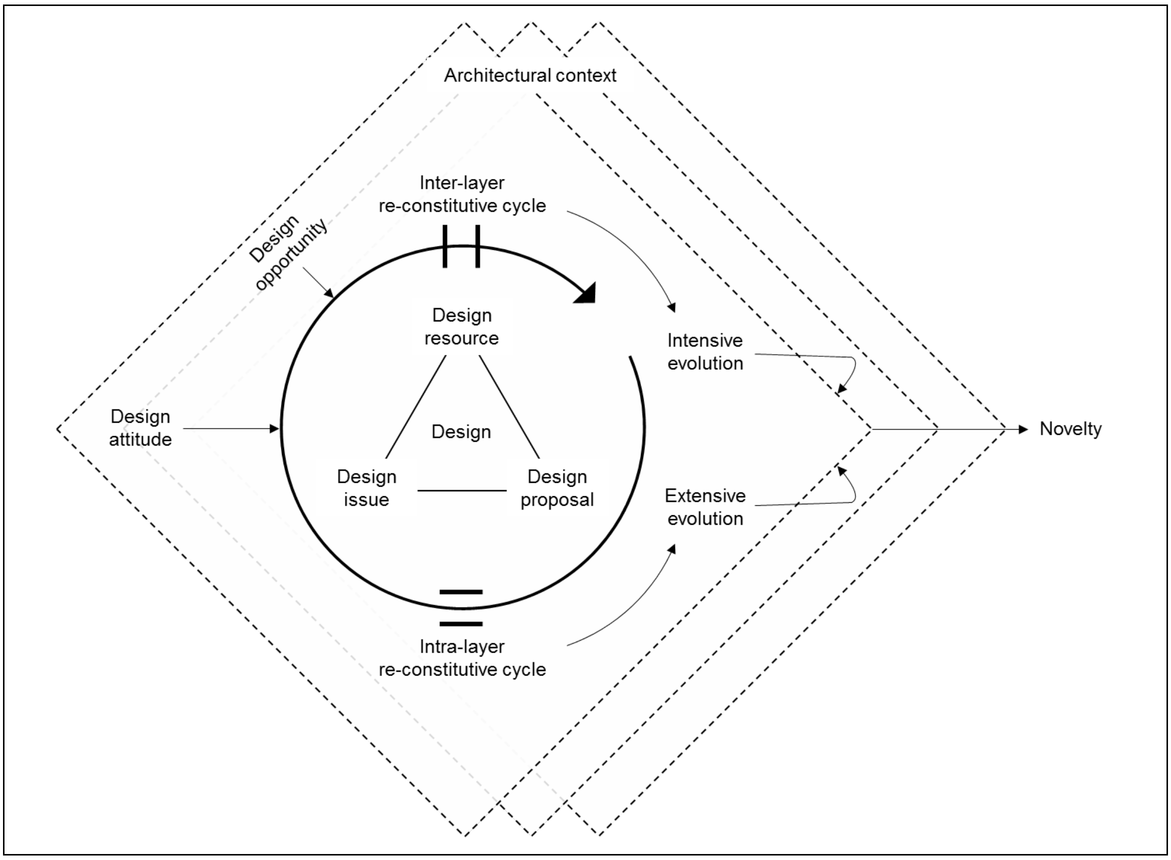
Re-constitutive cycles	Evolutions	
	Intensive	Extensive
	"beautiful" level	

However, two outliers are witnessed. The intra-layer reconstitutive cycle that resulted in the joint operation business model was by nature a long-term partnership business than a one-off transaction. According to the manager of the New Business Development Department, TopTech was the only one that offered this model at least to his knowledge (at up to the moment of the interview). The in-house developed projection merging system resulted from an inter-layer constitutive cycle. Although it was faster, easier to use and more confidential, it was more a rewrite of the program than a redefinition of what the system was and what it should do. These outliers, as the chief director of Multimedia Development Department who was involved in the project since its inception explained in a follow-up interview, might result from the motivation behind each design. The first was to cope with an unavoidable problem that no existing means to their knowledge was effective. They had to think out of the box. In contrast, the latter started with engineers' thought that "we can do it as well". Hence, it was destined to think in the box that was to handle the task with their conventional means.

4.6 Discussion and Implications

The starting-point of this research is the observation that the ease and speed by which digital innovation can be accomplished (see e.g., Nambisan et al., 2017, Yoo et al., 2010b, Yoo et al., 2012) also means that it is more difficult to stand out (see e.g., Boudreau, 2012). In innovation involving significant resources and effort, such as digital product innovation (Lyytinen et al., 2016, Svahn, 2012), this presents a dilemma, since seeking to make innovation standing out from the crowd will be of great importance.

Consistent with prior innovation literature (Garud and Karnøe, 2003, Jelinek and Schoonhoven, 1990, Van de Ven et al., 2008), this study shows that novelty is not created in one radical leap. Rather it is a step-by-step process where the novelty is emerging (Garud et al., 2006). However, in digital innovation, the layered architecture of digital technology (Yoo et al., 2010b) shapes the emergence. In this study, I discover how the innovation process unfolds over time through intra-layer and inter-layer reconstitutive cycles that evolve its design. I understand this as a process of reconstitution (see Figure 4.3).



Constructs	Definitions	Detailed explanation
Design	A temporarily stable constitution of three interrelated constituent elements (design resource, design issue, and design proposal).	*Design resource*: Believes, values and knowledge that shape design decisions by identifying and formulating design issues and evaluating and justifying design proposals. *Design issue*: What a design is formed for. *Design proposal*: What a design offers.
Design attitude	Designers' expectatoin about the most ideal status of the final design outcome, which orients their design	Its specialized and localized forms by different designers become more specific personal requirments that guide their design activities.

	activities.	
Design opportunity	A chance to create a new design.	Emerged design opportunities fuel reconstitutive cycles. New design opportutnies emerge from the reconstitution resulted from reconstitutive cycles.
Architectural context	The innovation architecture which a design is created in and connected to.	The context is formed by other designs that are functionally or conceptually relevant to the design in question and enables and constrains the realization of the design.
Reconstitutive cycle	The moment of design evolution that lead to a new design that reconstitutes its architectural context.	*Intra-layer reconstitutive cycle*: All the elements of the triad of a design are from the same product layer. *Inter-layer reconstitutive cycle*: The triad elements of the triad of a design are from different layers.
Design evolution	The emergence of a new design that exceeds the old.	*Extensive evolution*: The new design follows the design logic of its antecedent. *Intensive evolution*: The new design challenges the design logic of its antecedent fundamentally.

Figure 4.3 A model of the design process of radical digital innovations

Design, Design Attitude, and Design Opportunity. The process of design is the process where innovation novelty is generated as a creative idea and gradually evolve to a useful form (Wilson et al., 2010). This study shows that the design process of digital innovation is continuously changing. It always pursuits a better chance to generate new designs overstepping old designs, which means all designs are merely stable at the moment and await being reworked towards better ends. Besides, this process is not totally grounded on a sound logical reasoning (cf., Simon, 1996) but can also be conducted on an expanding rationality (see Hatchuel, 2001) and opportunistic behaviors (see Guindon, 1990). For example, the futuristic appearance of the seat design was an opportunistic planning based on its designer's discovery of the new animation theme and looked irrational to subsequent animations. In this sense, two driving forces of this process are design attitude and design opportunity.

Previous studies argue that the recognition and exploitation of opportunities are fundamental to innovation (e.g., Sarason et al., 2006, Moon and Han, 2016). This study shows that when designing a digital innovation, the reorganization of opportunities for creating new designs often takes place when designers compare design outcomes with functional and their personal requirements. Therefore, the progressive rise of innovation novelty to the most ideal status that meets designers' expectation often requires a continuous comparison. In other words, the continuous comparison is maintained by design attitude. For example, the projector designer constantly checked the visual effect not only after the design of projectors but also after the design of the building and the animation.

This study reveals that consequences of a comparison are twofold. One is a compulsory appropriation of opportunities. For example, the building designer improved building design version 6 responding to the unneglectable building shaking problem in version 5. The other is an autonomous appropriation of opportunities. For example, the packaging designer created a one-container packaging by exploiting the opportunity enabled by the equal length of building frame rods. Different from the compulsory that refines a design to meet given functional requirements, the autonomous improves a design to meet designers' personal requirements that are often a specified and localized version of design attitude. For example, a design attitude in the digital theatre project was to make every creation perfect. This was interpreted as to develop as many related system functions as possible by the system designers in their design of the monitoring system. In this way, design attitude and design opportunity serve as driving forces to gradually evolve a design either to better realize design attitude or to improve on better opportunities.

Design Opportunity and Architectural Context. In terms of designing a digital innovation through recognizing and exploiting design opportunities, this study reveals that the design process is often recursive. A design is often created in an architectural context that consists of other designs enabling and constraining its realization. "Architectural" here stresses that other designs are functionally or conceptually relevant to the design. In this sense, the exploitation of a design opportunity is to embody a new form of interacting with other designs. In other words, design opportunity is defined by the architectural context. It also means that designs that are architecturally relevant to each other form the architectural context for each other. Therefore, the exploitation of design opportunities is at the same time the creation of new design opportunities (cf., Garud and Karnøe, 2003). This is the very nature of novelty as reconstitution, in which a novel design reshapes its architectural context while appropriating the context, which informs its new version in return or new versions of other designs in turn.

Reconstitutive Cycle and Design Evolution. This study shows that the recursive interplay between design and architectural context characterizes the process of novelty generation with a succession of reconstitutive cycles, in which design reworks reconstitute its architectural context that informs new designs. This study shows that design opportunities can be identified not only in the same location of a design but also in other places in its architectural context. For example, the leasing business model was designed to take advantage of the assemblability of the theatre enabled by the building frame design. Therefore, the creation of digital innovation often comes with movements of design locus in a layered architecture of digital innovation (see Henfridsson et al., 2014, Hylving and Schultze, 2013, Yoo et al., 2010b). Informed by the layered architecture, this study identifies two types of reconstitutive cycles - interlayer and intra-layer reconstitutive cycles. The study identifies a tendency that these two reconstitutive cycles may lead to different design evolutions. For example, when stayed on the form layer, building design (version 1 and 2) stuck to the appearance of conventional cinemas. However, when the designer adopted the theme emerged on the content layer, building design (since version 3) shifted to a futuristic appearance. This, as the finding section analyzed, is a shift of innovation approach that the creation of new design moves from better implementing design logics to creating new design logics.

Boland and Collopy (2004) argue that managing for innovation requires creating new options more than making an optimized choice from given options. The extensive and intensive evolutions that this study identifies is in line with this argument by showing that the improvement of given designs and the creation of new designs are two basic approaches to generating novelty. On the one hand, the extensive evolution lays the ground for designers to evolve a design intensively by reflecting on its accumulating embodiment (cf., Levina, 2005). For example, it was only when the science fiction animation took form, the building's and the seat's designers were able to appreciate the theme and decided to adopt it in their own work to create the new building and seat designs. On the other hand, the intensive evolution transforms the development path of a design and shifts to a new path that is novel and probably more innovative in comparison with the previous path (cf., Garud and Karnøe, 2003). For example, the emergence of the "flying car" animation shifted not only the design path of animation but also that of the whole theatre. This two design evolutions characterize the design process as a process in which intra-organizational "bricolage and breakthrough" (Garud and Karnøe, 2003) design paths intertwine and jointly embody and elevate innovation novelty.

4.6.1 Theoretical Implications

This study offers a number of implications for the digital innovation and received innovation management and design theories. First, this study shows that novelty generation in digital innovation comes with reconstitution of architectural context of design, which is enabled by the layered architecture of digital innovation. Because of the layered architecture, innovation becomes increasingly "product agnostic" (Yoo et al., 2010b, p.728). As a result, different from traditional innovation management that assumes a predefined product concept (Ulrich, 1995), it is more common that a digital innovation starts with a concrete definition. Even if there is a predefined product concept, it is not necessary for component designs to be regulated by it. Rather than being dominated by the predefined concept, component designs that are initially subordinate may seize the dominating position as the project progresses. For example, the first animation started as a component expected to fulfil the role as an "exciting" content. Its science-fiction theme that emerged later became a guiding concept of the whole theatre. In this regard, innovation novelty is more emergent than planned. Besides, innovation novelty is not realized by comparing a design and given criteria but generated when a design exceeds existing expectations, which hence transforms its old architectural context to a new architectural context.

Second, this study shows that boundaries of innovation space become fluid because digital innovation is often through recreating innovation space. Instead of a predefined problem solution space, digital innovation is characterized by an innovation space of fluid boundaries (Nambisan et al., 2017). The fluid boundaries are often attributed to the flexible recombinability of digital technologies (Nambisan et al., 2017). The novelty-as-reconstitution view of this study adds to this recombinability-based reasoning with an understanding that the design of digital innovation is rebuilding what it is building on. Traditionally, product development relies on holding design work onto a "right" path to a "right" direction by frequently comparing the work in progress with predefined measures (Holsapple and Joshi, 2002). However, design work in digital innovation relies more on the freedom to continuously identify and capture design opportunities. Novelty generation that comes with reconstitution of architectural context which maps all architecturally relevant designs that enable or constrain a design work. The recursive interplay between design and its architectural context implies as soon as design work appropriates design opportunities, it is highly likely to create new opportunities at the same time. In other words, innovation space changes at the moment it is defined. Such a recursive interplay of design and its architectural context can serve as one possible explanation of the mechanism of the fluid boundaries of innovation space (Nambisan et al., 2017) that indicates the "generativity" (Zittrain, 2006, p.1980) of digital innovation.

Third, this study shows that design in digital innovation is becoming hybrid in that the division between design-for-function and design-for-aesthetics is disappearing.

In traditional product development, design is divided into "hard design" (to create a design fulfilling certain functions) and "soft design" (to make a design visually appealing) (Moultrie and Livesey, 2014). In "real" and "actual" design (Visser, 2006, p.106) in digital innovation, however, the distinction between these two types of design is disappearing. This disappearing distinction is different from the argument that the denotation of "design" is becoming wider to incorporate both hard and soft design (Boradkar, 2010). It is more about how aesthetic pursuits drive design-for-function or functional requirements drive design-for-aesthetics. Furthermore, this study shows that "opportunistic processes" (Ball and Ormerod, 1995) becomes increasingly essential to design in digital innovation. The capture of design opportunities is not necessary to be a reaction to given requirements but can be a proactive appropriation and suggestion embodying designers' personal pursuit driven by design attitude. As a result, both the hybrid and the opportunistic characteristics suggest that, for better interpreting the hybrid and opportunistic aspects of design, it is necessary to expand the extant problem-solution pairing framework.

Traditional design literature (e.g., Dorst, 2006, Dorst and Cross, 2001, Hatchuel, 2001) deals with this challenge by arguing that problem and solution spaces coevolve as a design task progresses. That is to say, the given core problem is invariant and dominates throughout the design process. However, as evidenced by the compound ring beam and projector connector design, the core problem may change. The compound connector design expelled the dedicated projector connector design. To the projector connector designer, it was not an expansion around a core problem in a problem space, but a removal of the core problem and expunged the problem space around it. Besides, the "problem-solution pairing" framework overemphasizes the "rational and cognitive" (Buchanan, 1995, p.50). However, this study shows that a rational engineering problem may be handled with a solution that is presented due to personal preferences without a clear rational grounding (e.g., the futuristic seat design and the colored rod design); and hence, the solution is more a personal proposal. However, the terms of "problem" and "solution" embosks such a proposal nature of design. Therefore, this framework is not enough to answer questions, for example, how designers judge the relevance of serendipitous encounters to their current design, why designers decide to deviate from a given track, and how designers justify their arbitrary design decisions chosen due to personal preferences. To answer questions like these, more information about arbitrary design decision has to be taken into account. The new framework developed by this study allows future research to examine more such information and better study the hybrid and the opportunistic aspects of the design of digital innovation.

4.6.2 Practical Implications

The downside of digital innovation is the deluge of similar offerings that inundates an innovative product or service at a staggering speed. To succeed in the digital age, companies must make their offerings stand out from the crowd of similar products or services. This study shows that one way to achieve this goal is to adopt a layered logic as TopTech did. When adopting a hierarchical logic, designers start with a clearly defined umbrella design. What evolving are the components that are always expected to aggregate into the umbrella design. However, a layered logic distributes dominance and hence autonomy to different layers, which means it enables the umbrella design to evolve as components on different layers evolve. Therefore, layered logic fits particularly well with the design of an innovation that attempts to stand out from other innovations as it allows the emergence of an innovative whole that goes beyond the predefined innovation.

The TopTech case shows that, at the individual level, adopting a layered logic may enable designers to "think relatively context free" (Cross, 1985). Such a freed innovative mind is especially helpful for designers to take advantage of generative opportunities, when designers are granted with sufficient discretion and encouraged to make proactive changes. Due to the unpredictability rooted in the nature of digital innovation (Yoo et al., 2010b, Nambisan et al., 2017), it is increasingly unrealistic to predefine a perfect functional specification. Besides, a successful radical digital innovation, especially consumer electronics and entertainment products and services, have to be not only functionally superior but also aesthetically appetizing (Verganti, 2013). The unpredictability and the equal importance of functional and aesthetic requirements both rely on designers to exercise improvisation according to the actual condition and by consulting their own values and aesthetic judgment. A freed innovative mind with an encouraged discretion may enable designers to harvest different kinds of opportunities to contribute to innovation. That may lead to a blowout and then a cascade of innovations in the design of digital innovation which aggregate into an innovative leap that makes the innovation stand out from the crowd.

4.7 Conclusion

This research conducted an in-depth case study of a project of a truly innovative digital theatre to investigate the research question: *What is the process by which digital* *innovation generates novelty in its output?* It reveals that digital innovation generates novelty through a process in which intra-layer and inter-layer reconstitutive cycles continuously improve product design extensively and intensively. This research provides several directions for future research.

First, previous studies often assumed a predetermined umbrella concept dominating throughout a design process. However, this study shows that a dominating concept is more emergent than predetermined. The degree of its domination changes along with the design process. This emergent characteristic of dominating concepts is worth future research on 1) how a concept gains the power to dominate and 2) how the degree of domination changes.

Second, organization design often corresponds to product architecture (Yoo et al., 2010b, Henfridsson et al., 2014). Besides, in TopTech, since it started as an animation company, the content department was its largest department, and “passion for perfection” from “artistic temperament” was enrooted in the company culture that exerted a powerful influence on even non-artistic designs, e.g., the building frame. Hence, future research could study how the emergence and change of the dominating power of a product component are related to organization design or vice versa.

CHAPTER 5 PAPER 3 – STRATEGIC SWAYING [2]

5.1 Introduction

Two-sided digital platforms are an increasingly important business lever to not only large companies but also startups. Building on King's (2013) definition, a two-sided digital platform refers to a digital product or service created by a third party to serve as an intermediary that connects two business actors and facilitates transactions between them. As online auction, homestay, and car rental websites and mobile applications have demonstrated, two-sided digital platforms have the potential to ignite an unstoppable momentum that snatches up market share from incumbent companies (Van Alstyne et al., 2016).

The key to unleashing the potential of a digital platform is its user base (Kelestyn et al., 2017, Tucker and Zhang, 2010). From a network effect perspective, the value of a platform to users on its either side depends largely on the number of other users on the opposite and the same sides (King, 2013, Eisenmann et al., 2006, Van Alstyne et al., 2016). Hence, to attain a critical number of users is vital to the survival and success of a digital platform business (Evans and Schmalensee, 2010, Van Alstyne et al., 2016, Eisenmann and Hagiu, 2008).

Extant literature offers plenty of valuable suggestions for growing a digital platform's user base. Most of them rely on a clear technological edge (Ghazawneh and Henfridsson, 2013), a significant first-mover or installed-base advantage (Gawer and Cusumano, 2008), or deep pockets (Eisenmann et al., 2006) of platform owners. However, they are challenging for most startups to apply.

In the situation of startups – especially in the early stage of their business, they rarely have obvious advantages in terms of market positions, financial resources, and technological offerings. Instead, they often start from the bottom of a market. They may suffer from limited access to financial resources (Romanelli, 1989). It becomes even more challenging when they are in the mobile application business where the hurdle is so low that new competitors keep entering the market and producing similar offerings (Boudreau, 2012). We have a very limited understanding of: *How startups grow their user base in disadvantageous conditions?*

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[2] Wang, G. and Nandhakumar, J., 2017. Strategic Swaying: How Startups Grow Digital Platforms. In *Proceedings of ICIS 2017.*

I conducted an in-depth case study (Gerring, 2007) at a Chinese digital startup that successfully developed its digital platform business without a technological edge, a significant first-mover or installed-base advantage, and a deep pocket. The data analysis revealed an effective strategic practice, called "strategic swaying”, that creates and executes specific digital platform growth strategies. As the dual meaning in the dictionary definition of “sway” implies, *strategic swaying* refers to a strategic practice in which a platform owner moves between users on two sides of the platform to influence the users’ activities.

This study contributes to the literature by outlining in detail the importance for platform owners to align offline and online efforts when growing its user base. It reveals the importance to adopt an all-rounded perspective when creating and executing digital platform growth strategies to make up their lack of technological, market, and financial advantages. The findings also have implications for research on the governance and the launch of digital platforms.

The paper is organized as follows. I firstly explain the critical role of user base in a digital platform business from a network effect perspective and also discuss digital platform growth strategies presented by previous studies and the reason why it is challenging for startups to apply. Then, I introduce the research approach of this study, including the background of the case, data collection and analysis, which is followed by an explanation and discussion of the findings. At the end of this paper, I discuss theoretical and practical implications and offer directions for future research.

5.2 Theoretical Background

5.2.1 The Importance of User Base to Digital Platform Business

A two-sided digital platform, such as a broker platform like Airbnb or Uber, connects two business actors (e.g., buyers and sellers) and mediates their transactions (King, 2013, Eisenmann et al., 2006). Its competitive advantage comes from the capability to tap into network effects (see Kelestyn et al., 2017, Van Alstyne et al., 2016). *Network effects* (also known as “network externalities”) refer to that the utility of a product or service to a user depends on the number of other users (Varian et al., 2004). Network effects are either positive or negative. A *positive network effect* refers to a positive correlation between the utility of the product or service to a user and the number of other users, while a *negative network effect* refers to a negative correlation between them (Kornish, 2006, Asvanund et al., 2004).

With different research focuses, network effects can be categorized in different ways. For example, network effects can be divided into direct and indirect network effects. A *direct network effect* means that the utility of a product or service to a user directly depends on the number of other users of the same product or service, while an *indirect network effect* means that the utility depends on the number of users of complementary products or services (Clements, 2004, Podoynitsyna et al., 2013, Varian et al., 2004, Shy, 2011). When examining a platform, network effects can be classified into cross-side and same-side network effects. A *same-side network effect* refers to that the utility of a platform to a user depends on other users on the same side, while a *cross-side network effect* refers to that the utility depends on other users on a different side (Li et al., 2010, King, 2013, Eisenmann et al., 2006, Dewan et al., 2010).

Since network effects underlay the dynamics of a digital platform business, its user base is critical to its success. The ideal state of the business is to have a virtual cycle where an increasing number of users on one side of the platform keep attracting new users on the same or the opposite sides, which in turn engage more users (Choudary et al., 2016, Van Alstyne et al., 2016, Edelman, 2015). For this purpose, previous studies have presented many useful digital platform growth strategies.

5.2.2 Digital Platform Growth Strategies and the Challenge for Startups

A *digital platform growth strategy* directs platform owners to define their desired ends (not necessarily to be the number of users, e.g., service quality and the position in a technological ecosystem) and to design a set of specific instruments and activities for achieving the ends, which eventually contributes to the growth of their user base. I have identified three types of digital platform growth strategy in the extant literature as follows.

Resort to Economic Means: Research (Eisenmann et al. 2006, King 2013) shows that economic means such as the charge on transactions have a significant influence on users' participation on platforms. Hence, by giving subsidies or discount to one side of a platform, platform owners can increase users on that side rapidly, which in turn attract more users on the other side, and eventually, the whole user base grows exponentially (see Eisenmann et al., 2006, Economides and Katsamakas, 2006, Dou et al., 2016). For example, PayPal's use of gift money to new sign-ups triggered a rocketing growth of its user base at the rate of seven to ten percent every day (Choudary et al., 2016).

Manipulate Technological or Organizational Characteristics of Platforms: Clarifying characteristics of the platform business by comparing it with the pipeline business, Van Alstyne et al. (2016) point out that a platform business requires a shift of mindset from resource control to resource orchestration, from customer value to ecosystem value, and from internal optimization to interactions between external producers and consumers. This assumes that platform owner has supremacy over an attractive platform. The strategic aim, hence, is to promote "core interactions" on a platform (i.e., interactions valuable to the platform) and to grant access to right players (Van Alstyne et al., 2016). For example, Apple opens up iOS with a multitude of application programming interfaces (APIs) that invite third-party developers to create complementary applications, which attract more non-developer users (see Ghazawneh and Henfridsson, 2013, Eaton et al., 2015).

Avail of the Achievement of Previous Businesses: Some platform owners may have various advantages accumulated through their previous business, for example, a huge group of existing customer and a massive install base (Edelman, 2015, Gawer and Cusumano, 2008). Companies may even transform their full-fledged products or services into a platform (Zhu and Furr, 2016, Hagiu and Altman, 2017). For example, Microsoft Internet Explorer was bundled to the widely used Windows and soon won a large number of users (Gawer and Cusumano, 2008). Similarly, Google directed users of its previous services to AdSense and quickly created a huge user base for the new platform (Edelman, 2015).

However, those strategies are challenging for startups to apply since startups often face financial, technological, and market adversities. Specifically, the majority of startups do not have a legacy of a previous business and often start from the bottom of the market. Besides, startups may live on a very tight budget. For example, Airbnb's founders lived on selling cereals to raise money for their business at the beginning of their business (Clemons et al., 2010). While creating a rapid growth of the user base, giving out gift money is also creating a rapid growth of cost depleting the platform owner's budget (Choudary et al., 2016). Startups may also lack a technological edge. Especially in the mobile application industry, similar ideas and competing applications are astonishingly abundant (Boudreau, 2012, Malizia and Olsen, 2011), which makes it difficult to attract users to create complementary offerings. Even worse, a platform may face the risk of being enveloped (Eisenmann et al., 2006) or simply being imitated (Zhu and Furr, 2016) by companies that are much more resourceful.

Therefore, although the extant digital platform growth strategies are still generally instructive for digital platform business, startups must be aware of their limitations. They should consider what strategies are available in their disadvantageous conditions and how to create and execute the strategies, which is the research problem this study addresses.

5.3 Research Approach

5.3.1 Research Site

I conducted an in-depth case study (Gerring, 2007) at a Chinese digital startup, MobiCo (pseudonym) in 2015. The company was incorporated in 2013. At the time of this study, it had thirty employees, with twenty-four at its headquarters and six Sales and Marketing staff working in other two cities. The company started with a tight budget around 70,000 US dollars, which was just enough for the salary of its initial seven employees for about a year, let alone other operating costs such as travel expenses and advertising fees. The financial status became even more severe due to the hire of new employees and trial-and-error costs of product and service development.

The empirical focus of this study was a digital platform, BrokerApp (pseudonym), developed and operated by the company. It was a mobile application connecting individual car owners and car repair shops (Figure 5.1). On the latest version of this application, car repair shops could post their services, while individual car owners could search for services that they needed.

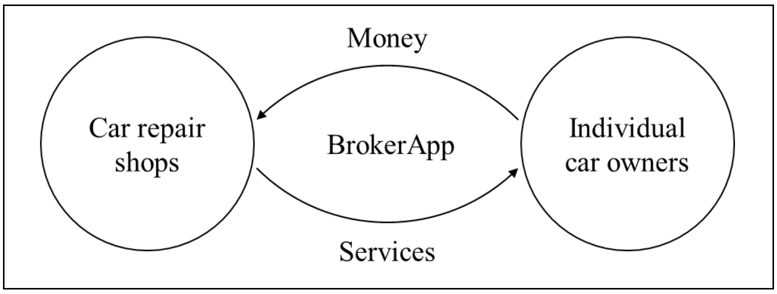

Figure 5.1 BrokerApp as a two-sided market

With limited resources, MobiCo successfully increased users on both sides of BrokerApp. Specifically, at the time of this study (one and a half years after its launch), BrokerApp had 100,000 active individual car owners and 700 car repair shops monthly, which generated a stable cash flow that enabled MobiCo to sustain its business. This achievement met the requirement of a venture capitalist who eventually offered MobiCo around $700,000 investment.

This study focuses on the period before MobiCo obtained the investment. I investigated how MobiCo managed to grow BrokerApp 1) with a tight budget, 2) when there were a large number of similar mobile applications (no fewer than a hundred on the Android platform and more than forty on the iOS platform), 3) without any famous member in the company, and 4) without a previously established reputation in the business. Next section introduces the data collection and analysis.

5.3.2 Data Collection and Analysis

I conducted data collection and analysis in a parallel and iterative fashion, where data analysis started as soon as data collection began, and I revisited research site with analysis results to verify and update the results with new data. The purpose of this continuous interplay between data collection and analysis was to deal with biases in qualitative research, in addition to deepening my understandings and improving the quality of my interpretations of the data (Whittemore et al., 2001).

Biases that possibly found their ways to this study would be caused by informants and researchers. Possible biases would also take place in different research stages (sampling, data collection, and analysis). To deal with the biases, this study paid special attention to consistencies between different data types, between different data sources, between data collected at different times, and between informants' and researchers' interpretations (Whittemore et al., 2001). For example, to minimize biases in interviewees' retrospective reports, I consulted relevant project documents and interviewed multiple persons who were involved in the same task with the same question. I also asked some interviewees the same question several times in different ways. To avoid researchers' improper interpretations of data, I asked key projector members to evaluate my interpretations. Only interpretations that they agreed on were incorporated into further analysis and theorization.

In total, I conducted twenty-five semi-structured interviews with twenty-four interviewees (with the CEO interviewed twice) with each interview lasted thirty to ninety minutes. The interviews covered all managers and staff from all departments at the headquarters of MobiCo (see Table 5.1). I tape-recorded all interviews with permission, and then transcribed all recordings for analysis.

Data analysis consisted of four stages (see Table 5.2). The first stage developed a detailed historical understanding of the company and its products and services. The second stage identified and extracted empirical data closely related to my research focus. The unit of analysis of this study was events related to the attraction and sustainment of both individual car owners and car repair shops. The third stage was to develop descriptive codes, to identify first-order categories, and to group the categories into second-order themes (Saldana, 2009). The fourth stage defined constructs and analyzed their interrelations for model building.

Table 5.1 Information of interviewees

Departments	Main Functions	No.
Chief Executive Officer	Raising funding, making critical decisions, allocating resources, etc.	1
Administrative Personnel	Human resource, accounting and finance management.	1
Technology Development	The development and maintenance of the digital platform.	6
Sales and Marketing	Market research, expanding new markets.	5
Customer Service	Handling car owners' complaints, guiding them through installation, reporting technical problems to Technology Development Department, reporting service problems to Merchant Management Department etc.	3
Merchant Management	Handling car repair shops' complaints, guiding them through installation, guiding the shops to create company profiles and to post services, reporting technical problems to Technology Development Department, etc.	4
Operations [3]	Planning and organizing events, conceiving strategies for future development of the digital platform and the company, etc.	4
Total		24

Table 5.2 Stages of data analysis

Stages	Descriptions	Outcomes
Coding development process	Identify products and services the company offered since its beginning.	Table 5.3 Chronology from MobiCo's First Product to BrokerApp
Coding events of attracting and sustaining individual car owners and automobile repair shops	Identify and excerpt data related the company's efforts for searching, increasing, and keeping individual car owners and automobile repair shops.	Table 5.4 Exemplar Instruments of Increasing the User Base
Coding and clustering of concepts	a. Develop descriptive coding. b. Identify first-order categories. c. Group the categories. d. Define second-order themes.	
Developing a model	a. Define constructs for model building b. Analyse the interplay between constructs.	Figure 5.2 Strategic Swinging

5.3.3 Case Description

This section introduces a five-stage development of MobiCo's products and services (see Table 5.3). This chronological review of the development process shows

[3] "Operations" is a department name given by the company, although the department had nothing to do with operations.

how MobiCo gradually formed their understandings of the business, which laid the ground for the development and operation of BrokerApp.

Table 5.3 Chronology from MobiCo's first product to BrokerApp

Stages	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Offerings	Fleet management system	On-board diagnostics (OBD) system	Utility mobile application	Membership management mobile application	Two-sided market
Targeted users	Institutional users	Individual car owners	Individual car owners	Car repair shops Individual car owners	Individual car owners Car repair shops
Functional descriptions	To monitor institutions' cars in terms of locations, working hours, and the like.	To record the conditions of various subsystems of the car.	To check real-time traffic conditions, penalty point record, etc.	To manage members' information, collect points, buy and spend vouchers, etc.	Car repair shops post services. Individual car owners search for, book services, and make payment.
Reasons of changes	The anticipated market size was small.	Few buyers. Collected data could not be reused for other business purposes.	If the company charged for the download, there would be few buyers. If the application was free, it would generate little business value.	The car repair shops' regular customers already got used to the old service process and did not have motivation to use the application, which means there were few incentives for the shops to adopt the application. This revealed that to extend customer base for the shops held the key for the adoption of the application.	

The first stage was a fleet management system for institutional users to monitor the location and working hours of their cars. However, it turned out that the actual market size was smaller than MobiCo's expectation. Considering the long-term growth of the company, MobiCo abandoned this product.

The next stage was an on-board diagnostics (OBD) system for individual car owners, which had a larger population than institutional users and the market size kept growing as there were a fast-rising number of individual car owners in China. The product was a device that could be installed in cars to monitor their conditions for self-diagnostic and maintenance. However, the company was disappointed again by the low number of buyers, and the data collected by the device was worthless for other business purposes.

The third stage was a utility mobile application that allowed individual car owners to see real-time traffic condition, to chat with other users nearby, to check penalty point reports, and the like for free. The problem of this application was that, like most free mobile applications, the company could not figure out an effective way to make money from it. Its development and maintenance consumed money continuously; whereas, few individual car owners were willing to pay for it, as there were too many similar free mobile applications.

The fourth stage was a membership management mobile application for car repair shops. With this application, car repair shops could create membership accounts for their customers. They asked the customers to download the application for booking services, making payments, collecting points, and purchasing vouchers. This application attracted some car repair shops at the beginning. However, feedbacks from the shops revealed that the added value of this application was limited. Major users of the application were regular customers of the shops, who got used to the old service process of the shops. Since the application did not bring new values to them, the customers were not willing to take the time to download and install the application and often forgot to use it. For this reason, the application generated minor benefits to the shops, and they showed signs of retreat.

The fifth stage was BrokerApp. It was a two-sided market that connected individual car owners and car repair shops. At the beginning, both sides could post messages on BrokerApp. On the one hand, individual car owners could post information about what kind of services they needed with information about their preferred areas and dates. Seeing the post, car repair shops competed for the job by writing replies with details such as prices and estimated man-hours. Then, individual car owners could pick a shop from the replies. On the other hand, car repair shops listed their services, and individual car owners searched the services they needed according to their preferred place and time.

Subsequently, BrokerApp removed the “reverse auction” function (i.e., individual car owners posted their needs and car repair shops bided on them). Different car repair shops used different car parts and paints and different repairing processes. It was difficult for individual car owners to know the actual difference between the services in the replies. The most lucid cue for choosing a service was the price, which was sometimes disappointing when individual car owners found that a cheaper service used low-quality parts and paints. This price-based selection also made car repair shops that were pursuing high-quality services feel unfair. Hence, BrokerApp retained only the "service listing" function (i.e., car repair shops listed their services and individual car owners chose a service) and progressively raised the quality of the services in the list through a series of efforts introduced in the next section.

5.4 Findings

Experiences in the four stages preceding BrokerApp revealed several insights for MobiCo to consider their subsequent businesses. Specifically, the fleet management system revealed that it was difficult to sell hardware to institutional users. The OBD device revealed that it was also difficult to sell hardware to individual car owners. The utility mobile application further revealed that the value of the software should be to add value to offline services. The membership management mobile application revealed that both individual car owners and car repair shops were critical to their business. These four stages gradually shifted MobiCo's focus from hardware to software and then to services, and from either institutional users or individual users to both of them.

The membership management mobile application and the early stage of BrokerApp further made MobiCo understand that the value of the mobile application should be to help car repair shops to reach more customers, and to help individual car owners to find better services. MobiCo realized that either of the two sides relied on its opposite side. The more individual car owners used BrokerApp, the more car repair shops would be willing to join the platform; the more car repair shops competed on the platform, the more possibly there were services that could meet individual car owners' preferences, and hence the more individual car owners there would be.

For this reason, on the occasion of considering how to grow the platform, MobiCo set up two goals: 1) To increase individual car owners, and 2) to increase quality car repair shops. A common way to achieve these two goals reported by literature (Eisenmann et al. 2006) and pointed out by MobiCo's CEO was to offer subsidies to either side. Subsidizing individual car owners would allow them to pay less and get more, while subsidizing car repair shops would enable them to offer more at a lower price. However, MobiCo was in very straitened circumstances. Hence, MobiCo formed and implemented two economical strategies (see Table 5.4), socializing and enfolding.

Table 5.4 Exemplar instruments of increasing the user base

Strategies	Instruments			Descriptions
Socializing	Online	Chat room		Several chat rooms on BrokerApp for car owners who had similar interests to communicate with each other.
		People Nearby		A function to check out who was nearby and to start a private chat.
		Stealing gasoline game		A resource management game on BrokerApp, in which car owners harvested gasoline every once in a while. Players were ranked by the amount of their gasoline. For harvesting gasoline, in addition to do it at their own stand by accomplishing given tasks, players could also steal other players' gasoline.
	Offline	User meeting		MobiCo periodically organized excursions, picnics and dinner parties.
		Peripheral gift		Labels, T-shirts, car body covers with BrokerApp's logo.
Enfolding	Online	Information standardization		Online guidelines of how to describe car repair services clearly, and required form fields made the provision of information compulsory.
	Offline	Service unification	Label and banner	To affix BrokerApp's labels on car repair shops' windows and to hang BrokerApp's banners over the shops' doors.
			Service manual and inspector	MobiCo created detailed guidance for all services in terms of materials and procedures, and required car repair shops to abide by the guidance. MobiCo sent mystery shoppers irregularly to supervise the implementation.
		Trusteeship management	Hosting	MobiCo managed current car repair shops for their owners based on a contract about the sharing of profits and losses.
			Franchise	People who wanted to open a new car repair shop join directly to the BrokerApp-authorized camp. They invested money to MobiCo, which took care of everything for them.

5.4.1 Socializing: Organizing the Buyer Side

The strategy that MobiCo adopted to increase individual car owners, which I term *socializing*, was to promote the establishment and growth of a society of them. Socializing was carried out both online and offline.

Online instruments. Instead of offering subsidies to individual car owners, MobiCo figured out several ways to establish a society for them through online means. For example, MobiCo added chat rooms to BrokerApp, where individual car owners could exchange information about their hobbies. There was also a function called

“People Nearby” in BrokerApp that individual car owners could use to see who was around them and to initiate a private chat. These two functions jointly afforded an active online society of individual car owners. However, this establishment of the online society was merely MobiCo’s first step of its socializing strategy. As a staff of the Operations Department introduced:

> *Chat room and “People Nearby” are another two popular functions… At the beginning, we added the chat room for people to share information about car maintenance or to ask for help… There is an obliging and active user group exchanging information in the chat room. We were told by some users and saw on “Baidu Tieba” [an online bulletin board] that when people asked questions about car maintenance, they were sometimes referred to use our application… Another interesting thing we found later was a rise in the number of users who used the chat room to look for people who had same hobbies and to organize ad hoc gatherings. So, we added “People Nearby” for this purpose. It also became easier to find help, for example, when you needed someone to help you change a tire.*

MobiCo also created an online game called “Stealing Gasoline” and periodically opened it for certain events. The most successful use of the game recorded was in an event organized by a local radio station and sponsored by a local bank. In the event, MobiCo acted as a technical support, while the bank offered the money. In the game, individual car owners competed for accumulating virtual gasoline. A player could steal gasoline from or fuel gasoline for other players. Players who attained 15-liter gasoline were rewarded with souvenirs that were provided by the bank. During the three-day event, the daily number of players reached 300,000, which was three times the number of monthly active users of BrokerApp. As the manager of the Operations Department explained:

> *Our goal was very simple, to spread the app. Apparently, if they [players] wanted to win, they needed to gain more gasoline quickly. They needed to steal more. But, it would be advantageous if there were more people helping them to fuel their tank. To do that, they would ask their family members, relatives, and friends that were not current users to join the game, which means, they spread the app for us… The events largely boosted the downloads of our app. Well,*

of course, not all of them became active users after the event. But, BrokerApp became a household name with what we already had. And, we paid nothing for the promotion… If you know that similar events will be held in the future, will you delete it [BrokerApp]? … One day, when they wanted a car service, this is their first choice, because they have already known, installed, and used it, and people who they know are using it. It is more trustworthy and ready-to-serve.

Offline instruments. MobiCo also organized offline events to promote the development of the society of individual car owners. MobiCo periodically organized user picnic, excursions, and dinner parties to create a chance for individual car owners to meet in person. In addition to offline events, MobiCo also gave individual car owners peripheral gifts such as labels, T-shirts, and car body covers, with BrokerApp's logo on them. These efforts aiming to enhance a sense of belonging to the society also contributed to the promotion of the application. As the CEO introduced:

There are too many companies in this business. Some big companies are also doing this business… We are just a tiny player. We are nobody. We don't have much money. If we want to survive, we need to try anything. So, we take what we already have [car owners] seriously. We must make them stay and see whether we can do more with that… we thought organizing offline gatherings might be helpful. We wanted to create a social bond between them [car owners]. It's like a university society experience… Anyone was welcomed. We encouraged them to bring their families and friends to the events… From their feedbacks, people did like it. And, we could see new people attending every time... I think this was also useful for the promotion of our app. Can you imagine the impact of our legion marching on the street? … Sometimes, when I met car shop owners, some people who came across the events before told me that it was impressive. Some of them said they thought we were a big company.

The effect of the online and offline socializing was obvious. As a staff of the Operations Department explained:

Generally, other companies are merely able to ask car owners to pay right before or at the time when they actually receive *a car service. It is because they [car owners] are afraid that the service they prepaid could not be fulfilled as promised. So, they don't want to take the risk to prepay the money to buy an expensive membership. In contrast, many of our users have prepaid for a year and the number of such users keeps increasing. It means that they trust us. The comparatively long term of prepayment also means we have a high stickiness that ensures them [car owners] to use it repeatedly.*

As such, the trust and stickiness facilitated the attraction and sustainment of individual car owners which made BrokerApp an attractive platform to car repair shops.

5.4.2 Enfolding: Organizing the Seller Side

The strategy that MobiCo adopted to increase quality car repair shops, which I term *enfolding*, was to organize car repair shops and standardize their offerings. The platform gradually became a wrapper of car repair shops.

Online instruments. As introduced before, MobiCo gradually realized that the diversity of services offered by numerous car repair shops had negative effects on both the individual car owner side and the car repair shop side. On the one side, it became difficult for individual car owners to choose among the large number of diverse services. On the other side, it resulted in cut-throat competition between car repair shops.

Reflecting on such a problem, MobiCo firstly required car repair shops to provide detailed information about their services. In addition to online guidelines of how to describe their services clearly, MobiCo also set required form fields to make the provision of information such as manufacturers of their car parts and paints and their repairing procedures compulsory.

Offline instruments. However, it turned to be still insufficient for individual car owners to know the actual quality of services, since few of them had sufficient professional knowledge to make the judgment. Besides, it was difficult for them to know whether a car repair shop offered services as they wrote. Hence, MobiCo decided to organize car repair shops and to standardize their offerings as it gradually gained bargaining power as the number of individual car owners grew. Two phases can be identified in the organization and standardization according to the degree of control over car repair shops.

Service unification: At the beginning, MobiCo sent its staff to check whether car repair shops that signed up for BrokerApp were legitimate to provide car repair services. They handed out labels and banners with BrokerApp's logo and brand name on them to the shops. Having the labels affixed to its window and the banners hung over its gate, a car repair shop could show its authenticity to customers. As the manager of the Merchant Management Department explained:

> *This authentication is meaningful to them [car repair shops]. Car owners care about whether the shops can handle their cars properly. And, they also want to be sure that they can find a responsible person if any trouble happens in or after a service. So, with our labels and banners, the shops can convince car owners that they are decent service providers. This is especially helpful for attaining customers who have not used their service before.*

As individual car owners on BrokerApp increased, MobiCo decided to strengthen its control over car repair shops in order to improve the quality of services listed. MobiCo created a manual with detailed guidelines for all services in terms of, for example, what materials and procedures should be used in a service, and required car repair shops to abide by the guidelines if they wanted to keep the BrokerApp-authorized shop status. To make sure that the shops were following the guidelines properly, MobiCo sent inspector (as mystery shoppers) from time to time to monitor their implementation of the manual. Shops that failed to fulfill their requirements would be firstly warned and eventually lose the certificate if they kept violating the guidelines.

Trusteeship management: The latest effort of MobiCo to organize and standardize car repair shops was trusteeship management. In a trusteeship management, owners of current car repair shops entrusted their shops to MobiCo. People who wanted to open a new shop could also delegate it to MobiCo. What the owners needed to do was to draw up a contract with MobiCo about, for example, the period and share of profits and losses. Then, MobiCo would do everything on behalf of the owners, from the (re-)decoration of their shops to the daily operation such as hiring, training and managing staff.

Service unification and trusteeship management were different in terms of the degree of control. However, they tapped into similar underlying logics. First, MobiCo leveraged the increasing number of individual car owners as a resource to bargain with car repair shops. Since the large number of individual car owners showed the potential to extend the shops' reach to customers, MobiCo persuaded the shops to accept the identity as a BrokerApp-authorized shop. Second, the increase of BrokerApp-authorized shops lowered the bargaining power of car repair shops while raised MobiCo's. Allying a large number of shops, it became difficult for a non-authorized shop to compete with BrokerApp in terms of area coverage and business image. Third, when car repair shops realized that it was a disadvantage to be excluded from the BrokerApp-authorized camp, MobiCo imposed a strict norm on their offerings, which increased the quality of services that individual car owners would access via BrokerApp and hence in turn further promoted the increase of individual car owners.

5.5 Discussion

5.5.1 Analytical Overview: Strategic Swinging

The above analysis shows that socializing and enfolding were two strategies MobiCo adopted to improve both sides of BrokerApp and hence the growth of the platform.

Socializing and enfolding often interweave with each other, which means each one of them facilitates its counterpart. For example, on the one side, socializing increased individual car owners which became a resource for MobiCo to bargain with and enfold car repair shops to improve the quality of their offerings; on the other side, enfolding increased good-quality services to sustain and attract current and new individual car owners. In other words, socializing increased the value of the platform to the car repair shop side, while enfolding increased the value of the platform to the individual car owner side.

Socializing and enfolding are also able to work on a single side without an immediate reliance on each other. For example, the offline meeting that socialized individual car owners resorted to their needs of belonging; and, the promotion of the BrokerApp-authorized camp created an unfavorable situation for non-authorized shops, which compelled them to join the camp.

While creating and executing socializing or enfolding strategies, a platform owner often needs to proactively move between two sides of its platform in terms of both vantage point and physical location, which I term *strategic swaying*. For example, in order to understand the value of the platform to car repair shops and the value of individual car owners to the platform, MobiCo took the vantage point of car repair shops and identified that the shops wanted to reach a wider customer base through

BrokerApp. Hence, the more individual car owners on BrokerApp, the more valuable it was to the shops. Similarly, MobiCo took the vantage point of individual car owners and identified that their interest laid in cheaper good-quality services. To achieve these identified strategic goals, MobiCo had to physically join and keep in touch with both sides. They had to organize offline events in person for individual car owners and to negotiate with and manage car repair shops. Even for establishing the online society of individual car owners, MobiCo appointed dedicated staff to break the ice in the chat rooms during the early period after its launch.

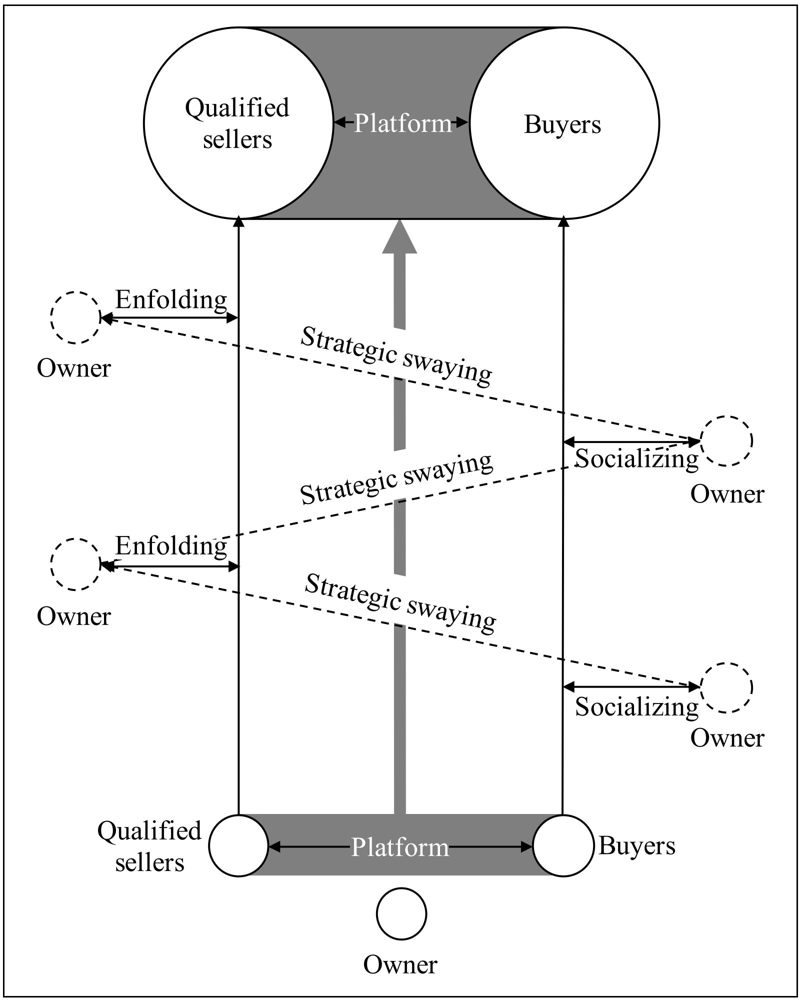

Figure 5.2 Strategic swinging

To synthesize above analyses, Figure 5.2 depicts a model of strategic swaying. In the figure, solid circles represent three actors of a two-sided digital platform: a platform owner, sellers, and buyers. Dashed circles represent participation of the owner when it moves to either side of the platform. The gray arrow pointing from the platform at the bottom with smaller seller and buyer groups to that at the top with larger seller and buyer groups depicts the growth of the platform as the seller and buyer grow larger. Dashed arrows labeled “strategic swaying” illustrate movements of the owner. Solid double-sided arrows are the owner's interactions with the sellers and buyers, which contribute to their growth.

5.5.2 Underlying Logic: Tapping into Positive Network Effects

Above analysis shows socializing and enfolding created and executed through strategic swaying helped BrokerApp to grow its user base steadily. Then, why they worked? This question can be understood with the previously introduced network effect concepts.

On the one hand, socializing increases positive same-side network effects by creating a sense of belonging on the buyer side. The strength and durability of the bond among buyers contribute to the expansion and sustainment of an offline buyer society. Such a society, especially the offline part, offers more incentives for users to participate in a platform than focusing on online community alone (Parameswaran and Whinston, 2007). The trust generated from the offline social bond can also be a valuable resource for growing the platform (Lee et al., 2015). Socializing also increases positive cross-side network effects by enabling sellers to reach more buyers. The healthy growth of a buyer society may increase the attractiveness of the platform to sellers (Tucker and Zhang, 2010).

On the other hand, enfolding reduces negative same-side network effects by reducing the huge amount of cheaper low-quality services to stop cut-throat competition on the seller side. Enfolding also increases positive same-side network effects by creating an authorized camp that a platform owner can leverage to unite sellers, which also eventually contribute to the reduction of competition and the creation of economies of scale. Economies of scale enable the platform owner to improve the quality of services while reducing the price, which is not possible for a single seller to achieve on itself. This simultaneous realization of the drop of the price and the rise of the quality contributes to the increase of positive cross-side network effects, which increase the attractiveness of the platform to buyers. Besides, enfolding the seller side also taps into positive indirect network effects to increase the utility of the platform to buyers because the collective capability of the authorized camp rises as its members accumulate. For example, a new BrokerApp-authorized car repair shop often expanded the area coverage of the whole authorized camp, which improved convenience for individual car owners to access the service.

As such, by creating and enhancing positive network effects and reducing and preventing negative network effects, strategic swaying enabled BrokerApp to form a "virtuous feedback loop" in which "greater scale generates more value, which attracts more participants" (Van Alstyne et al., 2016, p.58).

5.6 Implications for Research and Practice

Responding to the research question, I studied how a Chinese digital startup successfully grew its platform. I identified two digital platform growth strategies (socializing and enfolding) and a strategic practice (strategic swaying) that conceives and executes them. Through the lens of network effects, I also explicated the underlying logics that make the strategies and the strategic practice work. This study has a number of implications for both research and practice.

First, this study outlines in detail the importance of aligning offline and online efforts for growing the user base of a platform. Previous studies often approach the challenge of growing online users with an on-platform focus. They suggest platform owners grow online users with online interventions (Van Alstyne et al., 2016), such as offering new APIs (Ghazawneh and Henfridsson, 2013), reducing transaction fees (Eisenmann et al., 2006), and fake customer bot (Choudary et al., 2016). Although some works allow offline efforts to enter their examination of digital platform growth strategies, the offline efforts such as advertising are described in a negative tone as an outdated marketing approach (cf., Choudary et al., 2016). However, offline efforts never absent in stories of successful digital platform ventures and often play an essential role. For example, Airbnb hired professional photographers to take photos of apartments for hosts, which reduced friction for house owner users to join the platform, which attracted more lodger users (Guttentag and Smith, 2017). This study shows that even the most ordinary offline instruments can contribute essentially to the growth of a user base. For example, MobiCo's use of T-shirts created a seemingly united car owner society, which impacted and persuaded offline car repair shops to join the platform and also enabled interventions in the car repair shops for better services, which in turn attracted more individual car owners. Such a user growth chain realized by aligning offline and online efforts suggests that a more comprehensive understanding of digital platform growth strategies comes from examining the consecutive alignment procedures of offline and online efforts.

Second, this study reveals the importance of adopting an all-rounded perspective when conceiving and executing strategies for a platform. In line with previous studies, this study also confirms the essential role of economic means such as offering subsidies to price-sensitive side (Eisenmann et al., 2006) and technological means such as reducing friction by improving the searching process (Fath and Sarvary, 2003). However, this study also questioned the effectiveness of single-type accentuation by highlighting its limitation in the situation where platform owners do not have a particular strength in any of the resources. MobiCo's combination of diverse instruments such as chat room, online game, public relations event, social gathering, and franchise business suggests that digital platform growth strategies for startups should be examined with an all-rounded perspective to include, for example, social means. Besides, MobiCo's back-and-forth moves suggest that the complementary relationship between diverse resources is also essential to the effectiveness of a strategy. Therefore, it is not enough to only study how a single type of resource is appropriated to conceive and execute a strategy but also necessary to investigate how multiple resources (e.g., social means like MobiCo used) are used in combination, in a way that they complement each other.

Third, and relatedly, this study has implications for research on the launch and the governance of digital platforms. For platform launch research, this study offers insights into how startups decide which side to start when launching a digital platform. This chicken-or-egg dilemma haunts the launch of all types of platforms (see Evans, 2009, Choudary et al., 2016, Edelman, 2015). Previous studies often lay emphasis on choices driven by the principle of the *effectiveness of user satisfaction*. The strategies are to choose a side that is most sensitive to their technological, market, or financial advantages (e.g., Eisenmann et al., 2006, Choudary et al., 2016, Gawer and Cusumano, 2008). This study shows that choices of startups in disadvantageous conditions can also be driven by the principle of the *convenience of resource mobilization*. As the MobiCo case shows, a startup at the early stage of its business is more prone to finding users to whom they can apply their existing resources. The side to start, hence, is the side that is most approachable with the existing resources. If we trace back to the beginning of successful digital platforms such as Facebook and eBay, we can see that the very initial momentum originated in the participation of people who had a close relationship with the founders, such as their friends, classmates, and neighbors. The effectiveness of user satisfaction often comes into play after the momentum is formed. For this reason, a better understanding of startups' choice of which side to start should not neglect how the principle of the convenience of resource mobilization drive platform owners' decision.

For research on platform governance, this study underlines the importance to take users' off-platform activities into account. Extant literature on platform governance focuses on monitoring and controlling users' on-platform activities (Van Alstyne et al., 2016, Ghazawneh and Henfridsson, 2013). However, threats may exist in users' off-platform activities, which is especially true in a broker platform context where a part of the transaction may happen offline. As the MobiCo case and other cases (see e.g., Anon, 2017, McGoogan 2017) show, unfavorable off-platform activities on the one side may cause a loss to users on the other side and may drive them away. Hence, off-platform activities should be considered as an essential part of platform governance.

This study also offers practical implications. The major concern of platform owners is always how to increase their user base. This study offers companies two strategies (i.e., socializing and enfolding) that they can use in their business. It also offers a practice (i.e., strategic swaying) that companies can use to figure out new strategies. MobiCo's use of the two strategies reveals the importance to consider offline social incentives for increasing users on the buyer side, and the necessity to deliberate the trade-off between the quantity and quality of users on the seller side.

Besides, MobiCo's use of the two strategies also shows that the outcome of the implementation of one strategy supports the implementation of the other strategy. This suggests that companies can proactively appropriate cross-side network effects directly in their strategic activities. Rather than increase users on the one side and let the unleashed cross-side network effects work spontaneously to the other side, companies should consider how to proactively leverage the cross-side network effects on the other side for their strategic aims.

The strategic swaying that MobiCo gradually understood users' needs by moving between two sides of its platform shows that a platform is not only defined by its technological characteristics. Users on either side of a platform see the platform as an entangled bundle of its technological offerings and users on the opposite side. In this regard, companies should set aside their ideas about what their platforms are and try to understand how their platforms look like in the eye of users. Companies should not only analyze what users do online on their platforms but also need to go to offline fields to study users for making strategies to grow the platforms.

Finally, I note that my findings are limited to the extent that I studied a broker platform. As previously discussed, many broker platforms take off-platform activities as their essential part. Hence, I can only conservatively argue that the strategic practice and the two strategies are more beneficial to broker platforms. However, as we can see, an increasing number of owner companies of software platforms start to set a position called developer advocate, which is expected to maintain an active developer community to organize developers for a benign development of their platforms. Hence, we should not rule out the possibility to use the strategic practice and the two strategies I identified for other types of platforms. I believe that by taking an all-rounded perspective and considering the alignment of online and offline efforts when studying other types of platform, future research can attain useful and interesting insights.

5.7 Future Research

This study offers several directions for future research. First, future research can study a typology of online and offline strategic resources. Second, they can study whether and how the alignment of online and offline efforts in strategies for different types of platforms is different, and how does the difference come into existence. Third, what other digital platform growth strategies are available and effective for digital startups. Fourth, whether and when a platform owner that proactively participates in users' activities should and how to pull itself out of the intimate engagement.

Finally, I suggest future research to study how platform owners not only strategize for their platforms but also use the platforms as a strategic apparatus. The back-and-forth moves of the locus of strategizing that used a platform as a reference point and the push-and-pull activities that fuse the platform with users both indicate that the platform, the users, and the platform owner are not always "self-contained entities that influence each other" (Orlikowski and Scott, 2008, p.455). Rather, they mutually depend on each other while conceiving and implementing a digital platform growth strategy. Furthermore, the recurring strategic swaying witnessed in the case showcases that digital platform growth strategy is broadly the same as general digital innovation strategy, which is a continuous tailoring that keeps adjusting its operation as innovation progresses (Nylén and Holmström, 2015). The way that how platforms work and how they can be appropriated for maximizing business benefits is characterized by "a circular, iterative, feedback-driven process" (Van Alstyne et al., 2016, p.57). In this process, a platform should be seen as an entangled bundle of digital artifacts and users, which further indicates that digital platform growth strategies are a relational outcome of a historical progress during which the platform, users and the platform owner interact recurrently. All these characteristics (i.e., the entangling of a platform, users and a platform owner, their mutual dependence, and the historical process of their interactions) accentuate the importance for future research to study digital platform growth strategy from a sociomaterial perspective (Spee et al., 2012, Hall et al., 2013).

5.8 Conclusion

The power of a digital platform is often rooted in its user base. Hence, to effectively grow the user base is the most pressing task for a platform owner. My in-depth case study at a Chinese digital startup identified two specific strategies and a strategic practice that conceives and executes the strategies. The findings show that startups can grow the user base by moving back and forth between both sides of its platform to push and pull the users with online and offline efforts. Highlighting the importance of the alignment of online and offline efforts and an all-rounded perspective of strategizing, this study sheds new light on the research on digital platform growth strategy and also research on the governance and the launch of digital platforms.

CHAPTER 6 PAPER 4 – AFFORDANCE-BASED CONCEPTUALIZATION OF ADAPTIVE USE [4]

6.1 Introduction

Although enterprise systems (ESs) are widespread in organizations, users often find it challenging to leverage maximum benefits of the systems (Jasperson et al., 2005, Ross and Weill, 2002). To maximize the benefits, systems must be effectively used (Burton-Jones and Grange, 2013) and new uses of systems are essential to achieving effective utilization of them (Bagayogo et al., 2014). Such new uses could be trying out new system functions or adjusting a system for new tasks. Researchers (e.g., Hsieh et al., 2011, Sun, 2012, Chandra et al., 2012, Bagayogo et al., 2014, Hsieh and Wang, 2007) use different terms to refer to such new uses. Based on my review of their work, I refer to such new uses as *adaptive use*, which I define as using a system in a way that enriches working possibilities to benefit more from it.

A vast majority of the prior studies focus on how system use is shaped by material properties of technologies. However, Burton-Jones and Grange (2013) argues focusing on material properties is insufficient. They point out that "cognitively" understanding what to do with a system is also critical. Thus, to understand adaptive use, we need to explore users' perceptions of working possibilities a system offers.

For understanding such users' perceptions, researchers (e.g., Fayard and Weeks, 2014, Volkoff and Strong, 2013) increasingly see the concept of affordances, originated in the work of Gibson (1977), as a useful perspective. Previous affordance-based studies highlight how system use is shaped by material technologies (e.g., Majchrzak and Markus, 2013, Burton-Jones and Grange, 2013). These studies, however, have some limitations: first, they focus mainly on affordances of technologies; however, technologies are only a part of environmental surroundings of users. Other actors surrounding users also offer "the richest and most elaborate affordances of the environment" (Gibson, 1977, p.76). Second, few studies investigate the nested nature of affordances. Ecological psychologists (e.g., Stoffregen, 2003, Gibson, 1986) claim affordances are by nature nested and multi-layered, hence the relations between affordances are important. Although researchers (e.g., Fayard and Weeks, 2014, Volkoff and Strong, 2013, Burton-Jones and Grange, 2013) have acknowledged the

[4] Wang, G. and Nandhakumar, J., 2016. Affordance-Based Conceptualization of Adaptive Use of Enterprise Systems. In *Proceedings of ECIS 2016.*

importance of the relation between affordances and the nested structure of affordances, this has not been the main focus of previous works.

As a result, we only have a limited understanding of how different affordances interact with each other to offer possibilities of system use, especially adaptive use. To respond to this research need, this study sought to address the question: *How do affordances of a system and surrounding actors jointly shape users' perceptions of adaptive use possibilities the system affords?*

I focus this study empirically on an ongoing ES project in a large chemical company. The company claims that its efforts to promote ES use have brought about enormous improvements of its business operation. Due to its achievements in terms of ES use, SAP has selected the company as one of its model companies, and Chinese governmental authorities and industry associations have granted various ES use-related awards to the company. Drawing on the analysis of empirical data, this study makes three key contributions: first, I seek to contribute to adaptive use literature by exploring the perceptual linkage from multiple affordances to adaptive use; second, I propose a relational view of affordances by illustrating the interplay between multiple affordances; and third, I extend understanding of affordances in IT literature with the concept of human affordances and the dual quality of affordances.

The structure of the paper is as follows. In the next section, I review the literature on adaptive use, and affordances. I highlight the distinctive challenges to leverage maximum benefits of ESs in business organizations and the limitations of current theoretical perspectives. I then present the analysis of my empirical study. The subsequent section relates the empirical findings to existing theoretical perspectives to develop a novel understanding of adaptive use. Finally, I discuss implications of this study.

6.2 Adaptive Use of Enterprise Systems

Burton-Jones and Grange (2013) claim that effective use of information systems (ISs) holds the key to attain maximum benefits from the systems. Early studies (e.g., DeSanctis and Poole, 1994) consider *faithful use* (i.e., align with initial design) as a contributor to system success. However, there are inevitable misalignments and misfits between organizations and new systems, as the systems are usually designed for generic requirements (Gosain, 2004, Strong and Volkoff, 2010). Scholars suggest giving higher priority to resolve the misalignments and misfits; otherwise, they may result in detrimental outcomes (Majchrzak et al., 2000). Leonard-Barton (1988) claims an initial misalignment can be reduced gradually, however, the study by Majchrzak et al. (2000) shows aligning endeavours continue throughout a team's life cycle rather than arrive at a stable aligned state. Further, Jasperson et al. (2005) urge to expand currently limited uses rather than to stick to them in order to maximize benefits of a system.

Prior studies use different terms to refer to adaptive use, and each term is generated due to different concerns of researchers. For example, Hsieh and Wang (2007, p.217) use "extend use" and define it as "using more of the technology's features to support an individual's task performance". They concern what encourages users to use more features of systems. They argue prior direct experiences and learning processes familiarize users with systems. Such a familiarization allows users to go beyond standardized use and make more comprehensive and sophisticated use. Sun (2012, p.453) uses "adaptive system use" and defines it as "a user's revisions of which and how system features are used". He concerns the correspondence between environmental triggers and types of adaptive use behaviours. Chandra et al. (2012, p.799) use "adaptive use intention" and define it as "using a technology in a setting different from the one for which it was initially designed". They concern decision-making of adaptive use. From an information-processing decision-making perspective, they argue incomplete information along with a shift of use settings results in perceived cognitive burdens and risks. By allaying such burdens and risks, cognitive absorption and user trust fuel adaptive use intention. Bagayogo et al. (2014, p.362) use "enhanced use" and define it as "novel ways of employing system features". They concern how users deal with current and additional tasks with current, additional and extended features of systems. Their grounded theory approach distinguishes forms and attributes of adaptive use and influences of task characteristics, knowledge used, and system type on adaptive use.

Prior studies have offered various instances of adaptive use. For example, Burton-Jones and Grange (2013) present two actions that can be seen as adaptive use. One is adaptation that improves fidelity and accessibility of systems. Another is learning that improves users' knowledge about systems, and the domain, fidelity, and use of systems. Bagayogo et al. (2014, p.365-367) identify three forms of adaptive use: "using a formerly unused set of available features", "using features extensions", and "using a formerly used set of features to perform additional tasks". Sun (2012, p.458) identifies four behaviours indicating adaptive use: "trying new features", "feature substituting", "feature combining", and "feature repurposing". Chandra et al. (2012)

give out an example of adaptive use as to shift the use of virtual world technology from recreational purposes to workplace-related tasks.

Above terms, definitions and instances of adaptive use reveal essential characteristics of adaptive use. Reflecting on them, I identify four such characteristics. First, adaptive use manifests as users become increasingly familiar with a system. Second, adaptive use enriches working possibilities a system affords by improving either the technology or the user side. Third, adaptive use is expected to benefit more from a system. Fourth, adaptive use is jointly afforded by features of systems and organizational settings.

These characteristics seem to indicate adaptive use involves both material properties of systems and organizational settings surrounding users. Studies on material properties of technology (e.g., Faraj and Azad, 2012) suggest that affordances could provide an effective means of exploring the interrelation of users with specific technological objects. Following section reviews the notion of affordances.

6.3 Affordances and Its Nested Nature

Gibson (1977) originally defines *affordances* as a specific combination of properties of environmental surroundings (e.g., substances, surfaces, plants, human, and other animals) taken with reference to a perceiving actor. Affordances provide the actor with possibilities of certain actions. Gibson (1977, p.77) argues affordances are animal-relative but “not properties of the experiences of the actor exclusive of the things”. In other words, affordances exist before and do not depend on the perception of a perceiving actor.

Later researchers develop affordances further in diverse ways. Chemero (2003) distinguishes two research stances in affordance studies. The first (e.g., Reed, 1996) defines affordances as environmental resources existing prior to and waiting for perception and actualization. The second (e.g., Richardson et al., 2007, Turvey, 1992, Warren, 1984) defines affordances as dispositional properties of environmental surroundings that manifest when they are positioned in appropriate circumstances (e.g., the coexistence of properties of other objects or the effectivity of a perceiving actor).

Rejecting the idea that affordances are properties, Chemero (2003) presents the third stance seeing affordances as relations between features of environmental surroundings and functional properties of a perceiving actor. This definition takes into account that a perceiving actor is fallible even in appropriate circumstances. This definition also stresses mutuality between a perceiving actor and his/her environmental surroundings. This stance highlights the role of human agency that is critical in the conceptualization of system use practices (Faraj and Azad, 2012, Jarzabkowski and Kaplan, 2015). Thus, I adopt this definition of Chemero (2003) in this study, since it has more explanatory power to examine adaptive use.

Affordances are by nature nested (Gibson, 1986), or multi-layered in Stoffregen's (2003) words. Because the environment is always "structured in a hierarchy of nested units" (Gibson, 1986, p.22), higher-level affordances always consist of lower-level affordances (Stoffregen, 2003). Lower-level affordances are often indispensable for leveraging higher-level affordances (Burton-Jones and Grange, 2013, Volkoff and Strong, 2013). This is because higher-level affordances are usually synergistic outcomes of nesting processes of lower-level affordances (Stoffregen, 2003). As Stoffregen's (2003) baseball example shows, the affordance of a sequence of pitches cannot be attributed to any single pitch. This also implies that affordances are relational, which means not only the different affordances but also the relation between them enables higher-level affordances that make corresponding actions possible.

The nested nature of affordances reveals the importance of examining multiple affordances and the relation between them. When studying affordances in the context of system use, besides the affordance of a particular system, we should also examine other kinds of affordances and the relation between them. However, this aspect of affordances has not been explored much in extant IS literature. As the following review shows, the main focus of extant IS literature is on the technology affordance of a system, rather than multiple affordances, the relations between them, and how they jointly afford system use.

6.4 Affordances and Technology Use

In IS research, technology affordances have been proposed as powerful means of analyzing "technology appropriation process" (Faraj and Azad, 2012, p.237). *Technology affordances* refer to "action potential, that is, to what an individual or organization with a particular purpose can do with a technology or information system" (Majchrzak and Markus, 2013, p.832). Prior studies (e.g., Markus and Silver, 2008) discuss what and how a technology affords for users. Although a technology affords possible actions, it is users who choose whether and how to actualize the action possibilities (Hutchby, 2001, Jarzabkowski and Kaplan, 2015). Different users may perceive the same technology affords different actions, and the same technology may afford different actions for the same user in different contexts (Hutchby, 2001).

However, few IS studies focus on affordances of other actors surrounding system users, which I call "*human affordances*" in this study. Human affordances can provide a perceiving actor with action possibilities directly, through the interaction between two persons in a reciprocal manner. For example, the teaching behaviour of teachers is afforded by the learning behaviour of students, and vice versa.

Human affordances can also provide a perceiving actor with action possibilities indirectly, through the mediation of material environmental surroundings. Karoff and Johansen (2009, p.240-241) depicts a trampoline play scene that is a good example pertinently demonstrating how human affordances work in this indirect way:

> *When I stand on it, the mat makes my body go up and down, small jumps, apparently almost by itself. When more than one person is on the trampoline together, the feedback changes... Oliver told me… that one of the reasons why he loved the trampoline so much was because of his body size. Oliver is a small boy, also in weigh, so when jumping around with his older brother Sam and father, he was the one, who had the most fantastic jumps of the three of them, not because he was good in jumping, but because the size and weight of the other, made his little body jump very high up in the air.*

In addition to providing a perceiving actor with action possibilities directly and indirectly, human affordances change the "affordance-effectivity structure" between the actor and environmental surroundings (Richardson et al., 2007). This means human affordances can potentially enhance a perceiving actor to better perceive and actualize affordances. For example, compared with doing it yourself, you are more likely to perceive a grand piano affords carrying if there are other actors suggesting moving it together.

Scholars (e.g., Dokic, 2010) from different theoretical perspectives also acknowledge the importance of the presence of other actors at the scene where an actor behaves. They present ideas like "interpersonal agency" (Smith et al., 2000, p.458) and "perceived agency" (Gray et al., 2012, p.103). However, human affordances have different focuses. First, human affordances focus more on low-level details and dynamics. As Dokic (2010) claims, the perception of various kinds of affordances lay at least partly the ground for the sense of agency. The discussion of human affordances examines processes not only prior to actual behaviours but even before the sense of agency. Second, human affordances focus on the perceivable "beingness" of affordances (i.e., exist before and do not depend on perception). In other words, it focuses on the materiality of the bodily presence of other actors. The bodily presence is a material ready for perceptual processes of a perceiving actor. In contrast, an interpersonal agency is more like a capacity manifested through a process of exerting the capacity, and a perceived agency is more like a result of perceptions. Third, human affordance focuses on the relation between a perceiving actor and perceived actors. However, an interpersonal agency is on the side of a perceiving actor. It is a capacity belongs to the perceiving actor to form intentions and to initiate interactions to cooperate with perceived actors to reach a goal (Smith et al., 2000). A perceived agency is on the side of a perceived actor. It is an inferred conclusion of a perceiving actor about "target person's mind" (Gray et al., 2012, p.113).

Like in the general context, human affordances are also essential for understanding system use behaviours. However, this kind of affordances has been absenting from system use literature so far. Prior works use social rules (Hutchby, 2001) and social meanings (Fayard and Weeks, 2007) to explain influences of other actors on users. Their studies provide valuable insights. However, they do not give a thorough explanation how the materiality of the bodily presence of other actors shapes system use.

There are many situations where certain system use is not possible unless other actors physically present. For example, in an indirect use (i.e., mediated by support staff), the presence of support staff affects users' satisfaction (Kraemer et al., 1993). In addition, users lacking abilities to change a system may only perceive the system as changeable when IT staff exists (Leonardi, 2011). Further, adaptive use is sometimes triggered by deliberate initiatives initiated by other actors' requests (Sun, 2012). Such system uses are jointly afforded by the material presence of systems and the bodily presence of other actors.

For this reason, a comprehensive understanding of adaptive use should also involve human affordances of other actors, the relation between human and technology affordances, and how they jointly afford system use. Examining only technology affordances limit our understanding about the diversity of affordances and the relation between multiple affordances that shape system use. To address this research need, this study empirically investigated an on-going ES project.

6.5 Research Approach

I conducted a qualitative study (Orlikowski and Baroudi, 1991), focusing on system use practices in the post-implementation stage of an ongoing SAP ES project in a large company. My empirical inquiry also traced users' views back to the periods prior to the targeted ES through interviews with managers and staff who had sufficient experiences with former systems. This was because the current perception and use of a system draw on the previous technological and organizational infrastructure (Leonardi, 2011) and previous using experiences (Burton-Jones and Grange, 2013, Hsieh and Wang, 2007).

6.5.1 Empirical Setting

PriChem (pseudonym) is one of the largest chemical companies in the world with its headquarters based in China. It employed around 8900 employees and distributed in eleven countries. The company was renowned for its successful ES use that brought about extraordinary improvements of business operations. China National Chemical Information Center and China Information Industry Trade Association granted the company several ES use-related awards. SAP recognized it as a model company of ES use. Such an empirical context seems to offer a valuable setting for understanding adaptive use.

6.5.2 Data Collection

Interviews, the main part of data collection, were conducted in November 2013. To obtain comprehensive insights, interviewees were selected from all key departments (i.e., Top Management Team, Procedure and IT, Accounting and Finance, Human Resource, Purchasing, Warehouse, International Business Support, Marketing, and Manufacturing departments) and ranged from top managers to operational level staff. There were 20 interviewees in total. All interviewees had been deeply involved in the SAP ES project. In the interview, I adopted a "snowball" sampling strategy (Biernacki and Waldorf, 1981). I started the first interview with top managers, to get a better overview of all company operations. Then, reflected on the information they provided, I refined and expanded the existing questions for further interviews. After each interview, I asked interviewees to recommend others for subsequent interviews. In this way, interview questions were continuously improved, and more informative interviewees were involved in the investigation. This approach ensured increasingly improved data quality as the interview progress. Each interview lasted about forty-five minutes to an hour. Topics were primarily about individual actors (e.g., who the related actors were, and what their relationships were), systems used (e.g., what the systems were, and what functions they offered), thoughts (e.g., what initial goals the actors had, and how they perceived about the systems), actions (e.g., how the actors interacted with each other and the systems), and outcomes (e.g., what the gain and loss was). I tape-recorded all interviews with permission and then transcribed all recordings. I also carried out additional follow-up interviews via telephone and email to clarify essential points.

In addition to interviews, I gathered relevant documentations and maintained field notes on observations. I gathered corporate information from internal (i.e., reports, meeting minutes, strategic plan, and company magazines) and external documents (i.e., financial magazines) to obtain a comprehensive understanding of the case.

6.5.3 Data Analysis

The analysis was conducted by the field researcher and the co-author. First, the field researcher categorized his observations, field notes, and interview transcripts. This involved writing monographs summarizing observations and analyses. As the coding categories emerged from the data, the authors discussed and challenged the field researcher's interpretations. These interactions usually led to further elaboration and refinement of the interpretation and the necessitated revisiting data and literature to figure out more appropriate alternative explanations. Such a discussion continued until both authors reach an agreement.

Figure 6.1 shows an example of key stages of coding and analysis with exemplary data. I use the characteristics of adaptive use identified in "Adaptive Use of Enterprise Systems" section as identifiers to detect key phenomena in the empirical data. Then, the instances of adaptive use identified in the section are used as sensitizing concepts (Walsham, 1995) for data analysis. Specifically, interview transcripts, field notes, and other materials (e.g., company magazines and online articles) were coded to identify extracts relating to adaptive use. Then, I focused on the identification of first-order categories based on how users came up with the need and what consequences a use resulted in. In the final stage of coding, I clustered the categories into two themes based on relationships between needed and actual adaptive use.

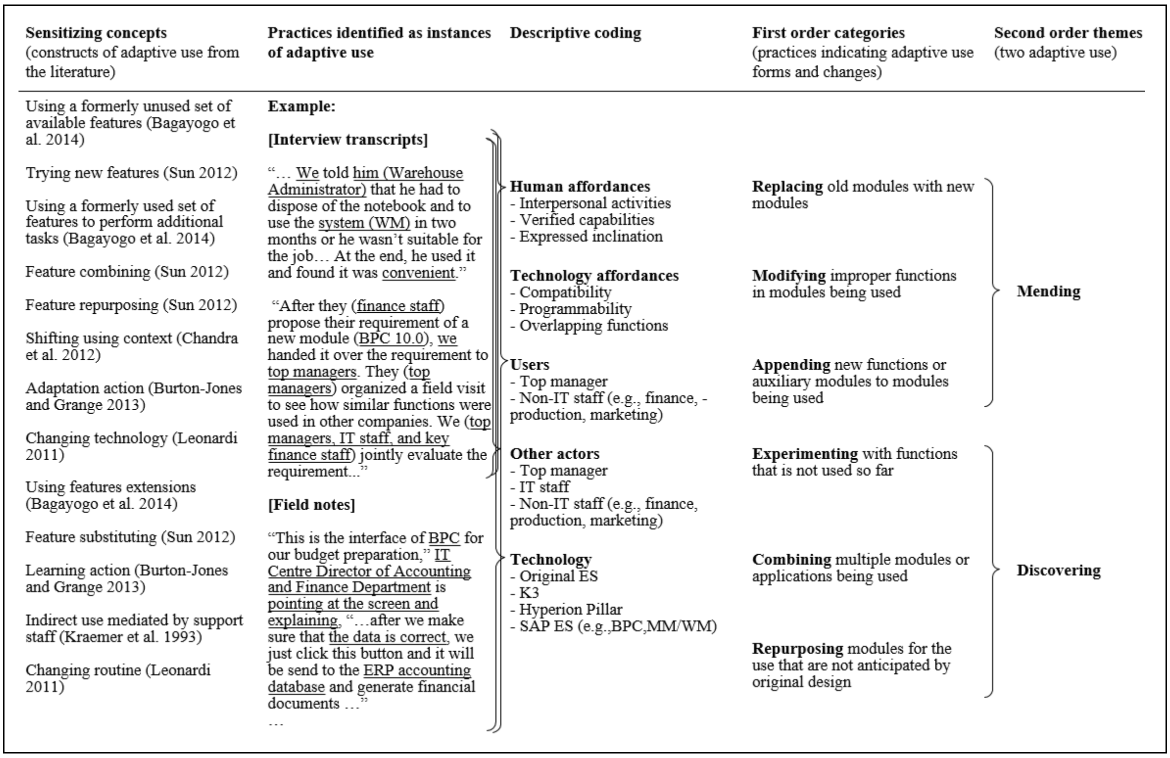

Figure 6.1 Example of coding and analysis of empirical material

6.6 Empirical Findings

Top managers of PriChem increasingly realized stricter financial management was indispensable for keeping a healthy business. Seeing the success of ES use of world-class companies, the top managers believed a more mature ES was able to meet such a need. In 1998, PriChem purchased two financial management systems and used them until 2008. The systems significantly raised the work efficiency of the financial department, however, they gradually reached their limits as PriChem continuously grew. Meanwhile, impressed by the findings that a large number of Fortune 500 companies and the top chemical company were using SAP products, the top managers decided to adopt the same SAP system.

Previous experiences realized the benefit of using ESs to support daily work. However, such a positive perception was limited to top managers, IT staff, and finance staff who were directly involved in the use. When PriChem started to implement the SAP system, staff of other departments was uncertain about its impact on their work. Many of them even had negative experiences with previous systems. Strong resistance to the new system was witnessed in many departments before the implementation.

To allay the resistance: first, the senior management sent core staff (potential key users) from each department to training programmes run by SAP and a Master programme of financial management run by a renowned Chinese university. The SAP training programmes aimed at increasing system-related knowledge of the staff, while the Master programme was to familiarize them with financial management. After the staff graduated from the programmes, they returned to their departments to lead implementation projects and to distribute the knowledge they learned. It was evident that the training brought about positive changes to their attitudes towards the system. Second, top managers divided IT staff into several sub-teams. Each team was allocated to a department to support daily use of the system. The day-to-day close cooperation offered IT and non-IT staff opportunities to build an intimate relationship. IT staff helped non-IT staff to implement and maintain the system. In return, non-IT staff helped IT staff to identify and target the logical error of the system. Such an interaction enabled a rapid increase of IT staff's business-related knowledge and non-IT staff's system-related knowledge.

The implementation was divided into three stages. The first, from 2008 to 2009, was to implement basic modules (e.g., procurement, production, sales, finance, human resources, and warehouse). Each module ran independently in corresponding departments. The second, since 2010, was to integrate the modules and implemented extension modules. The third, since 2012, was to deepen and expand system use.

In addition to basic use as planned, my data analysis identified two kinds of adaptive use, namely discovering and mending. I present key examples as follows to illustrate basic and adaptive uses.

6.6.1 Examples of Basic Use

One of the common use practices identified is *basic use*, which refers to actions abiding by the original plan of a system. The business cards application procedure introduced by the system is an example of basic use.

The General Manager of Process and IT Department said, "*When I need some new business cards, I have to fill out the online form* [technology affordance]. *The responsible staff will review the form. After s/he approved the application* [human affordance]*, the form will be transferred to the supplier of business cards.*" This is an "applying business cards" affordance mostly inclining to the system because users interact mainly and directly with the graphical user interface (GUI) of the system.

However, the General Manager also said, "*It is not rare that some people do not know the existence of the online form. So, when they go directly to the responsible staff and ask for business cards, the staff will tell them that they need to fill out the form first* [human affordance]. *Then, they have to go back to their desk, turn on the computer, and fill out the forms* [technology affordance].” This is an “applying business cards” affordance mostly inclining to the responsible staff because it was the direct interaction with the responsible staff made the applicant realize the existence of the GUI.

6.6.2 Examples of Discovering

One kind of adaptive use identified, which I name *discovering*, refers to actions actualizing new working possibilities of a system without changing its features. The most frequently witnessed discovering adaptive use in PriChem includes experimenting (e.g., trying the unutilized data mining function), combining (e.g., using BPC 7.5 module and Excel in combination), and repurposing (e.g., using BPC module to teach non-finance staff about the workflow, such as planning, budgeting, and reporting).

One of the witnessed examples was using BPC 7.5 module and Excel in combination to achieve a faster retrieval speed. The Budget Module Manager of Financial Department said, “*The BPC 7.5 was inconvenient… all logical relations were embedded within the form, the retrieval was very slow. If you use my computer, it might take 40 minutes to open this table* [technology affordance]. *This was intolerable to me.*” This problem was reported to the CFO/CIO. He asked IT staff to go to the financial department to help them figure out a solution to the problem [human affordance]. Meanwhile, because PriChem adopted diverse modules, they had a unified coding standard of data to coordinate the modules [technology affordance]. Thus, as following interview data shows, although IT staff can do nothing to improve the BPC 7.5, they figured out a way to bypass the problem without changing the BPC 7.5 directly. The Budget Module Manager said, “*We asked IT department to help us optimizing it. But, they were not capable of changing the module* [human affordance]. *So, we created and maintained a table at the backend to store master data. Then, we used Excel to access the table directly, which was a much faster way* [technology affordance]. *Now, it is less than five minutes.*”

6.6.3 Examples of Mending

Another kind of adaptive use identified is *mending*. It refers to actions actualizing new working possibilities of a system by changing its features. The most frequently witnessed mending adaptive use in PriChem practices included modifying (e.g., changing the code of BPC module), appending (e.g., adding iPhone applications to monitor the daily work of field sales representatives), and replacing (e.g., substituting BPC 7.5 with BPC 10.0).

The most frequently witnessed mending adaptive use was replacing inferior modules with superior ones, for example, the replacement of BPC 7.5 module with BPC 10.0. The BPC 7.5 module had several technological drawbacks (e.g., the slow retrieval speed mentioned above). The drawbacks were overcome by BPC 10.0 [technology affordance]. Besides the availability of the new module, IT staff also supported the replacement. The General Manager of Process and IT Department said, "*If you go to desks of IT staff, you rarely see them sitting there. They are usually staying in business departments* [human affordance]." Similarly, the IT Center Director of Financial Department said, "*When doing a project, we ask them [IT staff] to give higher priority to the project... They should stay with business staff at the site of the project... whenever they are needed, we can easily turn to them to ask anything* [human affordance]." This policy guaranteed that IT staff helped non-IT staff to establish appropriate anticipation about, to evaluate the usability of, and to implement the new module [human affordance].

Another example was the modification of the credit control module. A consultant of International Business Support Department said, "*We are refining a credit control module. Sometimes, customer companies might need to delay their payment… However, the system is too rigid* [technology affordance], *every time when we want to permit the delay, we have to go to responsible managers to ask for their permissions to change the data in the system. Actually, there were so many times that it was not necessary to ask for the permission... We discussed the problem of the module again and again with the IT department* [human affordance] ... *We searched for a new logic to reprogram the embedded processes together.*" Meanwhile, an engineer of Process and IT Department said, "*Their [non-IT staff's] IT skills are very limited. So, normally, they present their requirements to us. And, we evaluate their requirements and make the change for them* [human affordance]."

6.7 Discussion and Implications

6.7.1 Two Adaptive Use Practices and Their Characteristics

The analysis identified two adaptive uses: mending and discovering. As I have defined in the above section, *mending* is to actualize new working possibilities of a system by changing its features. It includes actions such as modifying, appending, and replacing. *Discovering* is to actualize new working possibilities of a system without changing its features. It includes actions such as experimenting, combining, and repurposing. Terms used for adaptive use in the existing literature are mainly descriptions of users' actual actions witnessed in the fieldwork. Even though the classification of the actions is exhaustive in the scope of the field work, new actions always potentially exist in other field work (e.g., Sun, 2012, Bagayogo et al., 2014, Chandra et al., 2012). For example, appending witnessed in this study is rarely mentioned in previous studies. Divided by changing system features or not, mending and discovering seem to be a more mutually exclusive, exhaustive and clearer classification.

In terms of emergence, mending is more premeditated, while discovering is more spontaneous or improvised. "Improvised" refers to the convergence of composition and execution in time (Moorman and Miner, 1998). As the example of mending shows, PriChem initiated new formal project teams with clear plans and schedules. However, the discovering that uses BPC module to teach non-finance staff about the workflow of the financial department was contingent and not predetermined.

In terms of consequence, mending is usually more durable than discovering. This is because mending often purposefully designs new affordances into technological objects (e.g., Gaver, 1991, Norman, 2013) or resolves constraints of technological objects by changing their material properties (e.g., Leonardi, 2011). Discovering, in contrast, does not change the material properties of technological objects. Newly discovered ways and functions may be abandoned as soon as they finish the duty unless users consciously record and spread them. If users do not reuse the newly discovered ways and functions, they will be gradually overlooked. For example, the company termly organized study groups to give staff opportunities to learn workflows of other departments. One way of the training was to show trainees workflows by walking them through corresponding system modules. However, some modules were not used in the study groups anymore, as no one was interested in the embedded corresponding workflows. Discovering has the potential to impact on future use when it enriches users' repertoire of system use by exploring new ways of using old known functions or uncovering hidden functions. For example, after tried the data mining function, which was not required before, scheduling staff of Manufacturing Department realized its value and routinized the use. However, even newly discovered ways of use and features are reused, they are not guaranteed to function well in future work since they emerge to deal with specific and contingent problems. As the problems change or disappear, the effect or the necessity of the ways of use and the functional features changes or disappears. In other words, discovering is situated. For example, the necessity of combining BPC 7.5 with Excel diminished, after BPC 10.0 replaced it.

In addition, both mending and discovering have the potential to generate innovative consequences. For example, appending iPhone as an extension of the system, and experimenting with data mining function resulted in process innovations of Human Resource and Manufacturing departments. However, discovering is more likely to bring about radical innovation, especially, repurposing. According to the definition of Norman and Verganti (2014), meaning shift is an essential source for radical innovations. Repurposing is the use shifting meaning of a system from designed fields to new fields, which itself is a kind of innovation and also introduce the opportunity to generate innovations.

6.7.2 More Than Technology Affordance: Human Affordance

Data analysis shows how systems and other actors jointly shape users' perceptions and actualization of adaptive use possibilities. On one hand, users perceive whether a system affords adaptive use through information cues such as the compatibility and programmability of the system and whether its functions overlap old systems. On the other hand, users perceive whether other actors afford adaptive use with interpersonal activities with and verified capabilities and expressed inclination of other actors.

The examples in the empirical findings illustrate that a good deal of adaptive use witnessed in this study was afforded by nested affordances aggregated from technology and human affordances, which cannot be attributed to either. In the business card application example, both the feature of the system and the presence of the responsible staff were requisite for users to use the system. Both the system and the staff regulated applicants' action options and directed them to the use of the online form. The system and the staff were not mutually separated but worked in combination to afford the desired use. Especially, in the second situation, when a responsible staff asked applicants to fill out the form, it was the staff and the form jointly indicating the availability of the business card application.

In the combination example, BPC 7.5 module, Excel, and the presence of IT staff were all requisite for users to conduct the combination of the module and Excel. IT staff was unable to modify the module. This restricted action options of users to change the module. Users had to find out a way to bypass the problem. The good news was that data in the database was managed according to a unified coding standard. Both the module and Excel enabled the access and process of the common data. In addition, BPC 7.5 and Excel served for different purposes. BPC 7.5 was used for updating the data file of searched result, while Excel was used for quicker retrieve in the file. They were merely connected by the file and did not overlap functionally. This means they were not substitutive for each other and did not result in redundancy of maintaining IT resources when used together. As a result, using BPC 7.5 module and Excel in combination turned out to be the most obvious choice of users.

In the replacement example, the technological superiority of BPC 10.0 was undoubtedly inducing users to adopt it. However, the replacement could not be conducted without IT staff, as non-IT staff did not have enough knowledge and skills to do it on themselves. It was the technological superiority and the competence of IT staff that jointly suggest and enable the replacement.

These examples show that both systems and other actors are indispensable whether it is basic use, mending, or discovering. As Gibson (1977, p.76) puts it, “behaviour affords behaviour... cooperative behaviour, economic behaviour, political behaviour - all depend on the perceiving of what another person or other persons afford”. The existence of other actors may change users’ perceptions and corresponding actions towards an object (Richardson et al., 2007), and we perceive action possibilities through the interpersonal environment (Fiebich, 2014). These arguments in previous studies and empirical evidence in this study jointly reveal the importance to consider affordances of other actors surrounding users, which I name it “*human affordance*”.

6.7.3 The Dual Quality and The Relational View of Affordances

The analysis reveals that, in the context of adaptive use, affordances can be both *enabling* (i.e., suggesting changing the system or the way of using the system) and *constraining* (i.e., suggesting sticking to current systems) at the same time. On the one hand, *enabling affordances* refer to action possibilities offered by features of systems and traits of other actors that suggest users to conduct adaptive use either on their own or with the help of other actors. Examples of such features and traits are sufficient system-related knowledge and skills of IT staff, being compatible with old modules, and being configurable and customizable. On the other hand, *constraining affordances* refer to action possibilities offered by features of systems and traits of other actors that suggest users sticking to a system and abiding by its embedded business processes. Contrary to those of enabling affordances, examples of such features and traits include insufficient system-related knowledge and skills of IT staff, and being incompatible with old modules and deficient functions. Enabling affordances are straightforward, as we are able to appropriate them to perform tasks when needed features and traits are in position. However, constraining affordances are counter-intuitive, since it seems arguing the absence or the deficiency of features and traits that is usually seen as constraints of some actions (i.e., adaptive use in this study) can actually afford the actions.

This extension of the concept of affordance is necessary. Taking the combination of BPC 7.5 and Excel as an example. When the IT staff was unable to reprogramme BPC 7.5, their inability was intentionally appropriated by users to conduct the use. What was the role of the inability here? Some studies (e.g., Leonardi, 2011) use "constraint" as the opposite of affordance. However, "constraint" has a weak explanatory power in this situation. If we call it the "constraint of combining", then combining should not happen. If we call it the "constraint of reprogramming", then is it irrelevant to "combining"? Such a situation is not rare in practices. This is why a new vocabulary "constraining affordance" is needed.

Possible explanations of the underlying logic of constraining affordances are twofold. The first is the aforementioned nested structure of affordances (Stoffregen, 2003, Gibson, 1986). It is true that constraints cannot directly afford adaptive use. However, it is also true that a constraint does contribute to adaptive use, as it is an indispensable component affordance nesting with other affordances to jointly form adaptive use affordances at the higher level. One thing to note is I am not arguing users can deny the materiality of systems. I agree that a constraint cannot afford what it constrains on its own. However, a user always has the choice to do otherwise when confronting a constraint, and the otherwise may involve properties of other surroundings and trigger the nesting process between the constraint and the newly involved properties. It is the nested affordance eventually afford the adaptive use. In other words, there is a transitive relation from the constraint to the resultant adaptive use. From users' point of view, the constraint is an indispensable part of the environment they directly interact with and perceive the possibility of the resultant adaptive use from the constraint.

The second is that new affordances may emerge from the relation between multiple affordances. Higher-level affordances are not merely a sum of different lower-level affordances (Stoffregen, 2003) but also incorporate the synergistic effect generated by the relation between the lower-level affordances. I call this *the relational view of* *affordances*. Such a synergistic effect of the relation has the potential to balance out the constraining effect.

6.7.4 Combinations of Affordances

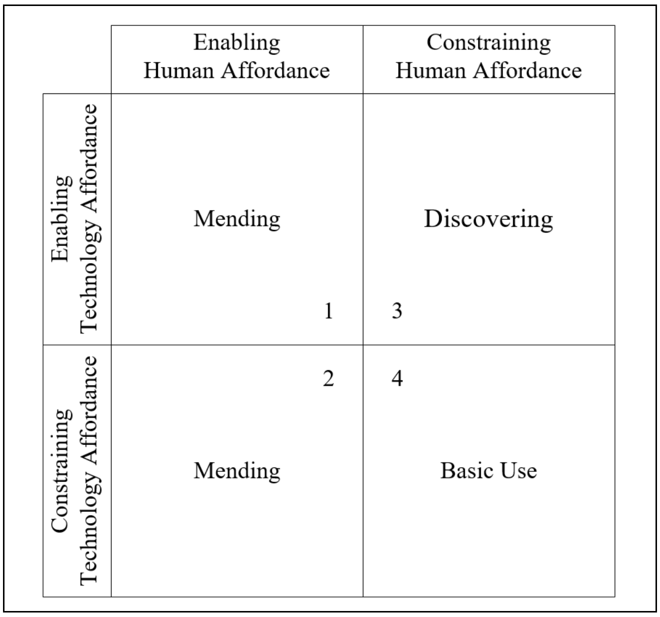

Figure 6.2 Four combinations of affordances

The analysis reveals that the relation between multiple affordances leads to four possible combinations and respective system uses (see Figure 6.2). In the first combination, both technology and human affordances were enabling (e.g., supports of IT staff who was able to install BPC 10.0, and BPC 10.0 was superior to BPC 7.5 and easy to install), and users are more likely to exercise mending (e.g., replacing BPC 7.5 with BPC 10.0). In the second combination, although technology affordances are constraining (e.g., the system was rigid to users), human affordances are enabling (e.g., supports of IT staff who was able to change the code of the module) may significantly broaden the range of users' perceived affordances of environmental objects (Scarantino, 2003), and users are more likely to exercise mending (e.g., reprogramming the code). Although the second and the first combinations both result in mending, the second mending's reliance on human affordances is higher than the first, since it needs to overcome constraining technology affordances. In the third combination, human affordances are constraining (e.g., IT staff could not reprogramme BPC 7.5), while technology affordances are enabling (e.g., BPC 7.5 and Excel used the same data format), and users are more likely to engage in discovering (e.g., using BPC 7.5 and Excel in combination). In the fourth combination, both technology and human affordances are constraining (e.g., the system constrained the business card application procedure, and responsible staff asked applicants to use online form), and users are more likely to stick to basic uses (e.g., using online form as designed).

6.7.5 Affordance-Based Model of Adaptive Use

Drawing on above analyses, I develop an affordance-based model of adaptive use (see Figure 6.3).

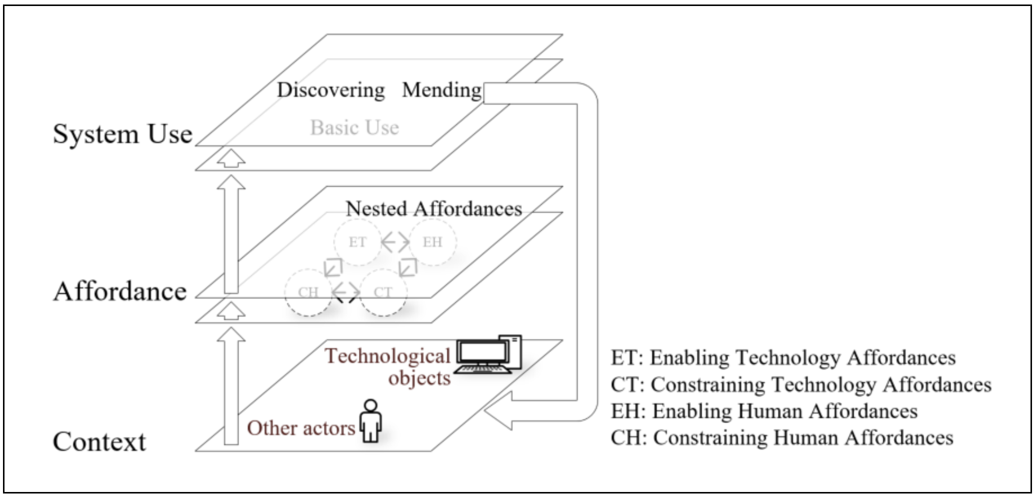

Figure 6.3 Affordance-based model of adaptive use

As discussed above, a system and other actors form the context of adaptive use by offering various combinations of diverse affordances. The system shapes users' perceptions of adaptive use possibilities with technology affordances, while other actors shape the perceptions with human affordances. The technology and human affordances can be either enabling or constraining adaptive use. The enabling and constraining technology and human affordances are not separated but interrelated, forming patterns of nested affordances. It is the nested affordances aggregated from the various enabling and constraining technology and human affordances and relations between them shape users' perception of possibilities of a particular system use. Perceiving possibilities of particular system use, users have options to either stick to basic use or engage in adaptive use. There are two kinds of adaptive use: mending and discovering. Both of them may have consequences influencing features of objects and traits of actors. The consequences change the context of future system use. Changes of the context alter affordances that users perceive and appropriate in the future use.

This study makes a number of contributions. First, it seeks to contribute to adaptive use literature by exploring the perceptual linkage from multiple affordances to adaptive use. Prior studies either assume when external triggers such as novel situations, discrepancies, and deliberate initiatives (Griffith, 1999, Sun, 2012) take place, users recognize technological constraints (Leonardi, 2011) and then form and execute the intention of adaptive use. However, the need to conduct adaptive use does not always result in adaptive use behaviours unless users perceive the behaviours as feasible (Pozzebon, 2001). The perception of the possibility is a significant antecedent of adaptive use behaviours. Drawing on the theory of affordances, this study shows that system use in general and adaptive use in particular are afforded not only by technological objects but also surrounding actors. Their affordances in combination aggregate into nested affordances that actually offer use possibilities. I suggest future research to pay careful attention to the diversity of affordances.

Second, it proposes a relational view of affordances by illustrating the interplay between multiple affordances. Although researchers (e.g., Burton-Jones and Grange, 2013) point out that there are diverse kinds of affordances and one affordance may be the prerequisite to leverage another affordance, their focuses are the capacity of each single affordance and the simple sum of their capacities. This study reveals that the relation between multiple affordances also plays a critical part in shaping users' perceptions of system use possibilities. This relational view of affordances is useful to understand the dynamic nesting process of multiple affordances and how constraining affordances are reversed in system use.

Third, it extends understanding of affordances in IT literature with the concept of human affordances and the dual quality of affordances. This study reveals that human affordances are equally important as technology affordances for shaping system use. This complements previous studies that focused purely on technology affordances. By incorporating human affordances, researchers are able to examine nested affordances of more complex system use. Moreover, this study also contributes the literature with the dual quality of affordances, especially, the concept of constraining affordances. This study shows that the absence of useful features of technological objects and traits of other actors also suggests adaptive use possibilities. This concept of constraining affordances echoes the idea of Nandhakumar and Jones (1997) that physical, social, and individual constraints traditionally seen as restrictive are actually able to provide action possibilities. This study further provides two explanations of the underlying logic of constraining affordances. I argue it is the transitive relation in the nesting process of and the synergistic effect of the relation between affordances reverse the effect of constraining affordances.

This study also has implications for practice. As shown above, adaptive use is a means to benefit more from current IS. Based on the insights this study reveals, I suggest practitioners to consider: 1) how to increase IT staff's presence in users' daily system use, 2) how to increase users' willingness of system use, and 3) how to improve the collaborative relationship between IT staff and users. The PriChem case offers several practices that can be a good model for practitioners to learn from. For example, in PriChem, IT staff was divided into several teams and sent to business departments to work with non-IT users day after day, which resulted in users' active, diverse and efficient adaptive uses. This can be a good model for CIOs to organize their IT department.

6.8 Conclusion

Drawing on an empirical study of an ongoing ES project, this paper explored the adaptive use of ESs. The findings indicate adaptive use is shaped by the nested affordance of technology and human affordances. This study also enables me to discover empirical evidence of adaptive use possibilities provided by technological, social, and individual constraints, and to develop the concept of constraining affordances. The affordance-based conceptualization of adaptive use provides a holistic view of the linkage from multiple affordances to adaptive use.

CHAPTER 7 GENERAL DISCUSSION

In using "harvest" as a metaphor in the title, this thesis emphasizes that a comprehensive picture of digital innovation requires understanding not only of the distributed nature of digital technology, but also of how actors proactively draw on it (Nambisan et al., 2017). "Harvest", as its dictionary definition implies, refers both to a product, ripe crops, and to the process of gathering. In this sense, both the characteristics of crops ready for collection and the collection process through which people take advantage of these characteristics are essential to the actualization of "harvest". Similarly, the actualization of digital innovation also consists of two essential parts: 1) the distributed nature of digital innovation that constitute opportunities for innovation, and 2) the intentional process of appropriating the distributed nature for a specific innovation. Just as the collecting process of "harvesting" allows the crops to be enjoyed, the appropriation process in digital innovation makes a socio-technical assemblage (Markus and Silver, 2008) and its changes relevant to the accomplishment of targeted innovations.

Bearing this idea in mind, this thesis has focused particularly on actors' intentional appropriation of the distributed nature of digital innovation to capitalize on innovation opportunities. The four studies (see Table 7.1) examine the four stages of the digital innovation process (Fichman et al., 2014). Each study investigates phenomena that are common and essential to digital innovation but have been disregarded by previous studies, thus contributing novel insights.

Table 7.1 Summary of the four studies.

	Study 1	Study 2	Study 3	Study 4
Themes	Representational practice	Innovation novelty generation	Digital platform growth strategy	Adaptive technology use
Innovation stages	Discovery	Development	Diffusion	Impact
Phenomena	Any project member may initiate a representational practice without the necessary knowledge or skills to accomplish the whole practice, enabling simultaneous communication and generation of ideas.	A radically innovative digital product design emerges from movements of the design locus among product component designers located on different product layers, without the direction of a dominant product design.	Digital start-ups often initially have limited resources, making it difficult to adopt strategies suggested by the extant literature to increase their user base. Nevertheless, many such start-ups manage to gain sufficient users without the back-up of such resources.	A digital technology may be used in a way that does not abide by its original plan but maximises the benefits of the technology.

	Study 1	Study 2	Study 3	Study 4
Findings	• Digital technology enables loose coupling between representational practice components with data homogenization and the flexibility to tolerate frequent changes. • Cohesive and serendipitous effect.	• Inter-layer and intra-layer reconstitutive cycles. • Compulsory and autonomous forces shaping reconstitutive cycles. • Intensive and extensive design evolutions.	• Socializing strategy for organizing online and offline users on the buyer side. • Enveloping strategy for organizing online and offline users on the seller side.	• Basic use as planned. • Discovering and mending as adaptive uses that exceed the planned way of use.
Theoretical contributions	• Explicates how data homogenization and the flexibility of digital technology result in a loose coupling of representational practice components. • Reveals two effects of combinatorial representational practice that either aid the coherence of idea communication or increase the serendipity of idea generation.	• Provides insights into how the layered architecture of digital technology results in digital innovation through movements of the design locus within and across product layers. • Explains the generation of innovation novelty as a process in which design reconstitutes its architectural context.	• Illustrates how the utility of a digital platform to a user depends on the number of other users and their interactions, posing a critical challenge to startups in the early stages of their digital platform business. • Offers understandings of how a platform owner may create and implement strategies to intervene proactively, not only online activities but also offline activities of users who lack technological, market or financial advantages.	• Highlights that users perceive possibilities of adaptive system use not only through technology affordances offered by the target system, but also through affordances offered by surrounding human actors. • Expands current affordance-based research with human affordance, a dual-quality and relational view of affordance.

7.1 Implications for Research

In line with the extant literature on digital innovation, this thesis has shown that the rapid and massive generativity of digital innovation (Zittrain, 2006) roots in the distributed nature of innovation enabled and enhanced by the unique characteristics of digital technology (Henfridsson et al., 2009, Yoo et al., 2010b). For example, novel ideas may be sourced from a boundless collection of representations created by a huge body of anonymous actors (Study 1); the progression of development may be driven by design decisions from any product layer (Study 2); and the utility and additional benefits of a digital offering may emerge from the participation of other artefacts and actors (Studies 3 and 4). As these examples demonstrate, characteristics such as data homogenisation and self-reference result in “form-function” and “content-medium” separation (e.g. Hukal and Henfridsson, 2017, Yoo et al., 2012, Kallinikos et al., 2013). This separation enables innovation generation to avail itself of heterogeneous intellectual, technological and market resources distributed in diverse human, material and digital components (Svahn et al., 2009, Nambisan et al., 2017, Nambisan, 2016) through limitless recombination of the components (Hukal and Henfridsson, 2017, Yoo et al., 2012, Kallinikos et al., 2013).

Although this thesis acknowledges the importance of understanding how the unique characteristics of digital technology fuel the distributed nature of digital innovation, it has argued that it is insufficient to examine only these characteristics, especially when empirical evidence shows that they do not necessarily produce favourable outcomes and may even present challenges to the pursuit of innovation (see, for example, Nambisan et al., 2017). The characteristics may result in, for example, less predefinition in innovation agency (Nambisan et al., 2017) that causes less coherent sensemaking that impairs collaboration for innovation (Study 1). To this end, rather than assuming that innovative outcomes are concomitant results of the characteristics of digital technology, it is also necessary to understand actors' intentional appropriation of these characteristics.

In devoting particular attention to the intentional appropriation, this thesis identifies diverse enactments of separation and recombination at different stages of the digital innovation process (Fichman et al., 2014). For example, at the discovery stage, actors generate and communicate novel ideas by taking apart existing representations and making collages of the needed parts to form new representations (Study 1); at the development stage, actors starting with separate component designs on different product layers frequently move between the layers to weave together component designs to realize novelty (Study 2); at the distribution stage, actors involve users through back-and-forth movements between users on different sides of a digital offering, detaching the offering from one side and integrating it into another (Study 3); and at the impact stage, actors use digital offerings in different ways to gain additional benefits according to the absence and presence of other human actors or technological artifacts (Study 4). These findings show that the emergence and appropriation of innovation opportunities at any stage of the digital innovation process occur through a consecutive process of separation and recombination. This process lays the ground for an iterative constitution of innovation opportunities (Fichman et al., 2014), in which actors' separation and combination of digital and non-digital resources in reaction to emerging opportunities often result in the emergence of new opportunities that lead to further separation and recombination.

Finally, the focus of this thesis on how actors in conventional positions appropriate distributed innovation opportunities while undertaking traditional tasks also contributes to the literature (see Henfridsson et al., 2014, Svahn, 2012). Previous studies' discussion of the distributed nature of digital innovation focuses on how digital innovation emerges from interactions between multiple heterogeneous actors in a distributed network (Andersen, 2016). Although they also consider how actors appropriate distributed innovation opportunities, they often adopt an "orchestrator" mindset (see Nambisan et al., 2017, Van Alstyne et al., 2016), which means innovating by preparing environments in which other actors can innovate (Hukal and Henfridsson, 2017). Combinatorial representational practice (Study 1), movements of the design locus (Study 2), moves between user groups (Study 3) and adaptive use informed by both technological artifacts and human actors (Study 4) direct the focus toward individual and interpersonal innovation activities that deserve deeper investigation. This thesis shows that, although the "orchestration" approach to innovation (Nambisan et al., 2017) is the most significant feature in the digital age, the intra-organisational process is still relevant, especially when a company is seeking to create something that is truly novel and beyond the imagination of the crowd.

7.2 Implications for Practice

Based on the research results, this thesis has argued that companies pursuing radical novelty in innovation generation should be capable of capitalizing on distributed digital innovation opportunities (Nambisan et al., 2017). The involvement of distributed actors and digital and non-digital artifacts makes the digital innovation process increasingly unpredictable (Nambisan et al., 2017). However, rather than being doomed by unpredictability (Menguc and Auh, 2010), it allows actors to encounter beneficial "accidents" (Austin et al., 2012) for truly new creation and value that go beyond the existing paradigm of innovation. Therefore, rather than sticking too closely to the minimization of "unpredictability" (Menguc and Auh, 2010), companies should embrace, maintain, and even encourage, "valuable unpredictability" (see Nambisan et al., 2017, Austin et al., 2012).

Companies may achieve this goal through either organizational or technological means. Each study in this thesis offers several specific means. For example, the results of Study 1 suggest that companies may create teams or departments dedicated to facilitating non-skilled employees in idea externalization, enabling all non-skilled employees to participate in and focus on the discovery of innovation. It also suggests designing new learning devices that facilitate design activities by incorporating inspiring extra information that is nevertheless relevant to a leading idea. The results of Study 2 suggest that product design and development should adopt a layered logic that grants autonomy to different layers, increasing the potential for component designs to push an innovative whole beyond the predefined innovation. The results of Study 3 suggest devising new strategic practices that proactively capture and leverage cross-side network effects. The results of Study 4 imply that companies should increase the physical presence of IT staff in users' daily technology use in order to develop intimate cooperative relationships between IT staff and users.

In addition to the specific means, this thesis also calls for a shift from a unilateral mindset (digital versus non-digital, or in-system versus off-system) to a relational mindset (dynamic and synergistic interrelationships between digital and non-digital, and in-system and off-system). Throughout the four studies, digital innovation emerges from "the constitutive entanglement of the social and the material in everyday organizational life" (Orlikowski, 2007, p.1435). In-system activities undoubtedly constitute a large proportion of interactions between human actors and digital technology that lead to the generation of innovation. However, the benefits of a digital offering to a group of human actors may rely largely on offline interactions between actors in the same or different groups. Similarly, perceptions and the fulfilment of a technology's function may be shaped by the physical presence of other human actors surrounding the user. Therefore, to better discover, understand and capture the existing and derivative innovativeness of a digital offering, it is important continuously to monitor in-system and off-system interactions between human actors, and digital and non-digital artefacts.

7.3 Future Research

This thesis has shown that digital technology enables professionals to take advantage of the distributed nature of digital innovation. The essential paradigm of digital innovation is the incorporation of new and the recombination of existing human, material and digital components to generate novel offerings (Yoo et al., 2012, Huang et al., 2017) and the release of ripple-like innovation momentum (Boland et al., 2007). In addition, the simultaneous realization of serendipity and coherence (Study 1), reconstitution of the design context (Study 2), strategic swaying (Study 3), and the aggregation of heterogeneous affordances (Study 4) share a common logic of innovation, in that they all tap into the redefinition of informational, intellectual, strategic, social and functional roles of separate components, and of relationships between them.

The new paradigm and innovation based on role and relationship redefinition reveal some correspondence between digital innovation and assemblage theory (DeLanda, 2006b, 2006a), suggesting the potential for adopting an assemblage theory perspective in future research to develop novel and in-depth understandings of digital innovation. The following paragraphs briefly introduce assemblage theory, link it to digital innovation research, and suggest several assemblage theory-based research topics by revisiting the future research topics proposed by each study.

A Brief Review of Assemblage Theory. In integrating his own and others' theory, DeLanda (2016) develops a fully-fledged assemblage theory. An assemblage is a collection of component things or persons and actions that form and sustain the collection (DeLanda, 2016). The theory emphasizes two aspects of assemblage: first, the components of an assemblage are heterogeneous; and second, an assemblage is not only a gathering of components, but also the establishment of interrelationships between them (DeLanda, 2016).

When applied to social studies, this theory explains how individual social entities make up lower-level social assemblages, which then aggregate to higher-level social assemblages (DeLanda, 2006b, 2006a). Applied to information systems (IS) studies, assemblages of humans and technologies may be seen as the ontological basis of IS phenomena (Cecez-Kecmanovic et al., 2014, Gaskin et al., 2014), and the concept of assemblage is used to explore the emergent properties of the information infrastructure aggregated from social and technical entities (Wynn and Williams, 2012). In both disciplines, component things or persons can be unplugged from one assemblage and plugged into others, and an assemblage at a lower level is a component of another assemblage at the higher level. Underlying the former is a logic of "relations of exteriority", which sees relations between two components as outside of them, referred to as the nested nature of assemblages, meaning that we are always dealing with "assemblages of assemblages" (DeLanda, 2016, p.3).

Treating all larger assemblages as a composition of components that themselves are smaller assemblages, DeLanda (2016, p.12) further posits that assemblages at all scales are on the same "ontological plan". Interactions between assemblages result in the emergence of new assemblages or the reformation of old assemblages, through "territorialization" and "deterritorialization" that form or reshape boundaries of components (DeLanda, 2016). In this way, assemblage theory reconciles the previously opposing upward determination and downward determination (DeLanda, 2016). With a "double determination", assemblage theory is equipped with the power to account for the emergent property of a whole, and is also able to explain why most components come into existence after the whole emerges (DeLanda, 2016).

Linking Assemblage Theory to Digital Innovation Research. The four studies in this thesis indicate that assemblage theory is compatible with digital innovation research. First, digital innovation is doubly determined: it always occurs through a two-way determination in which an innovation emerges from the collection of human, material and digital components and their interactions and, in turn, the innovation defines the entity of its components. For example, in Study 3, the digital platform business became a digital innovation through double determination. On the one hand, if MobiCo, the car service providers, the car owners and the BrokerApp had stopped interacting, the digital innovation would not have emerged or would have disappeared. On the other hand, the digital innovation defined MobiCo as an innovator, and the car service providers and car owners as users of the BrokerApp, directing strategic resources to MobiCo and functional benefits to each other, and the BrokerApp as an innovative offering. Similarly, in Study 1, the expression of an idea emerged in a combinatorial representational practice in which multiple actors, digital technology, and texts, drawings and 3D models interacted with each other. The meanings of the texts, drawings and 3D models, the roles of actors as ideators, creators or users, and the role of a digital technology as a design tool or mediator were all defined by the idea to be expressed – the purpose of the combinatorial representational practice.

Second, digital innovation unavoidably involves heterogeneous components (see Section 7.1). All four studies show that a digital innovation as an assemblage often involves diverse human, material and digital components (Svahn et al., 2009), which are intrinsically heterogeneous. In addition, components that are the same in nature may be different in form. For example, in Study 4, new uses of an existing technology were often jointly enabled by users, surrounding human actors and other technological artifacts, and interactions between them. In Study 1, although online blogs, photos and videos were of the same nature as digital representational objects of the same idea, they took different forms, presenting the idea with different information in different ways.

Third, territorialization and deterritorialiation are building blocks of digital innovation. The increasingly porous boundaries of the innovation process and less predefined innovation agency (Nambisan, 2016) both indicate that the process of digital innovation moves forward as an alternation between territorialization and deterritorialization. For example, in Study 2, the emergence and stabilization of a design ocurred through the definition of its design elements and justification of their relevance, which increased their level of internal homogeneity. Changes to a design may be caused by elements inside and outside the current design, and by re-evaluation of their relevance and redefinition of the design elements. Similarly, in Study 3, MobiCo's strategic swinging between different user groups continuously territorialized and deterritorialized the entity of the platform. For either of the two user groups, the platform was not only BrokerApp, but a set of BrokerApp and car owners from the car service providers' perspective, or a set of BrokerApp and car service providers from the car owners' perspective. Moreover, MobiCo's evolving business capability and its control over the application greatly affected the entity of all human and digital components and of the whole business by changing the material and expressive substance of the components.

Thus, there is a correspondence between constructs of assemblage theory and characteristics of digital innovation phenomena. The clarity of the theory's constructs and its well-developed internal coherence and consistency indicate its potential to serve as a useful common ground for researchers with diverse interests to achieve and communicate novel insights into digital innovation.

Assemblage Theory-Based Future Research Topics. The four studies propose several possible directions for future research, which might also be approached and further specified from an assemblage theory perspective.

Study 1 on representational practice calls for future research on how the role of a representational object may change without a change in the context of the design activities and design agenda. This research topic might be further deconstructed into several sub-topics from an assemblage theory perspective. For example, what critical component assemblages comprise the representational object that allow the change in its role? How do interactions between the internal component assemblages shape the boundary of the representational object that defines its role? What critical external assemblages interact with the representational object to clarify its boundaries and define its role? And how do external assemblages trigger changes in its role by interacting with the representational object at its boundary?

Study 2 on novelty generation calls for future research on the rise of dominating concepts. From an assemblage theory perspective, its sub-topics might include, for example: 1) how the dominant position of a concept is defined by its design elements through their interactions and the concept's interaction with other concepts; 2) how a product emerges from interactions between diverse concepts which define and redefine the dominant concept that currently guides its design process; and 3) how interactions between the respective assemblages of designers, concepts and works-in-process, and assemblages of a mixture of the three, shape the dominant power of a concept.

Study 3 on digital platform growth strategy calls for future research on offline and social means of digital platform growth. The strategic swinging practice demonstrated by the study is a perfect example of how digital innovation as an entity emerges from historical interaction processes between human actors and technological offerings. Adopting an assemblage theory perspective, sub-topics of this research might include: 1) broadening the ontology of digital platforms from a technological artefact to a socio-technical constellation, and studying how the entity of a digital platform emerges from interactions between its stakeholders; 2) viewing a strategic swinging practice as a process in which territorialization and deterritorialization of digital platform entity take place alternately, and studying how the entity of a digital platform shifts as its stakeholders interact; and 3) examining how entities such as "digital platforms", "functional components", "online actors", and "offline actors" at different assemblage scales overlap, and how these overlaps shape platform owners' strategic choices.

Study 4 on adaptive use sheds light on human affordance in technology use. Future research on the adaptive use of digital technology might include: 1) how surrounding human actors and technological artefacts mutually affect each other to form a boundary as a functional constellation that interacts with users and is seen by users as a holistic working function; 2) what features of human actors and technological artefacts play an expressive role, informing users of the boundary of the holistic functional constellation; and 3) how users' interactions with such a functional constellation sustain or reshape the boundary and thereby territorialize and deterritorialize it.

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